The Ophthalmoscope, its Theory and Practical Uses.

Vilas.

THE

OPHTHALMOSCOPE;

ITS THEORY AND

PRACTICAL USES.

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PREFACE.

This little volume is published to occupy a place hitherto vacant in medical literature, and supply a want which the Author has felt as a teacher. Much labor has been expended to make a book of practical value.

The Author regrets that in his endeavor to be concise, omit all unnecessary diagrams, and abstain from rendering the volume hard to the novice, he is compelled to forego discussing the higher mathematics involved. With the single exception of the slight reference under the subject of Ophthalmoscopic Optometry, and in the comparison of the direct and indirect methods, he has made no allusion to them. The advanced practitioner and specialist, and many of his later pupils, will therefore miss that which the Author regrets to omit.

Inaccuracies in the details of some of the black-board diagrams are unavoidable. Mathematical precision must not be expected in rude sketches drawn to enable the reader to lay hold on points seemingly a little obscure.

For his valuable aid, thanks are especially due to my assistant, C. F. Barker, M. D.; and to my house-physician, C. A. Dewey, M. D., for his assistance in proof-reading.

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THE OPHTHALMOSCOPE;

ITS

THEORY AND PRACTICAL USES.

INTRODUCTION.

The Ophthalmoseope is an instrument whose use permits of a thorough examination of the eye, without and within. This ean be aecomplished by no other device.

In many respects its use is like that of the otoseope, or laryngoseope; it would be even more like these instruments, but for the fact that its sueeessful use requires the harmonious adjustment of two eomplicated and separate dioptrie systems, the eye of the patient and that of the examiner. Such is the case with no other diagnostie instrument; henee the difficulty so often met with by the noviee.

This faet, thoroughly eomprehended, will serve to

eliminate all the discouraging elements, and enable the practitioner, with a small amount of labor, to grasp the wonders which the Ophthalmoscope reveals.

Previous to 1851, when Helmholtz published to the profession his invention of this instrument, beyond a few scattered observations, nothing had been evolved in the way of solving the problem of the illumination of the fundus of the eye. This had been due to the fact that it was believed that the choroid absorbed the rays of light reaching the fundus, and that none were returned. This error being practically refuted by this simple invention, a new era dawned in the progress of ophthalmic exploration. Not only was the special department of ophthalmological practice revolutionized, but many other branches of the healing art had their resources augmented as well.

Nearly all diseases of the eye posterior to the lens as now understood were either unknown, classed under amaurosis, or the subjects of mistaken conjecture. By one simple invention, the innermost and hitherto unseen recesses of the eye were lighted up, and the occult diseases placed within the range of the surgeon's vision.

Science under the impetus of this master-mind swiftly swept away musty theories, and a new literature displaced the old. Those diseases of the fundus which had never been seen in the living subject, are no longer the vaunting ground of conceited ignorance, but the best understood, perhaps, of any lesions of the human economy.

As the use of the instrument began to be known and appreciated in eye diseases, it was but natural that the phenomena here observed, should in time be associated with those occurring in more remote parts of the system. The results obtained have been most gratifying; for the ophthalmoscopic appearances of the *fundus oculi* are now recognized as important factors in the diagnosis of many diseases of the general system. Indeed if all is to be credited that has been written, there are few disorders in whose study and treatment, we may not bring the services of this instrument into requisition. That there are still great opportunities for discovery in this field of diagnosis, no one can doubt who is familiar with the present knowledge and recognizes the wide expanse unknown.

But it is essential that he who would use the Oph-

thalmoscope to good purpose must acquire, first, the knowledge of the optical principles of its construction; second, dexterity in using the instrument, and third, the power of understanding the significance of what he sees.

While the first may be easily overcome by a moderate amount of study, the mastery of the other two will depend greatly upon natural adaptation, and the perseverance with which are made careful and repeated observations and comparisons of facts. I will not disguise the fact that facility in the comprehensive use of this instrument is acquired only by patient, oft-repeated, careful effort; and he who would not stop short of the highest knowledge here, must as in all other valuable attainments, submit to the work inevitably preceding it. No one who uses this instrument well has picked it up and quickly flashed it to the elucidation of hidden structures; he has patiently solved the problems presented.

An endeavor will be made in this little treatise to comprehensively place these problems before the reader without unnecessary difficulties in the way of their easy solution, pointing out the shoals whereon so many are

stranded. The full understanding of all presented is necessary to a mastery of the instrument. Without it the practical attempts are like the wandering in the fabled maze—constant glimpses of an end never fully attained.

CHAPTER I.

REFLECTION, REFRACTION, AND THE FORMATION OF IMAGES.

When rays of light fall upon any surface, they are reflected, absorbed, or transmitted. Only a portion of light, however, which meets any surface is reflected; the remainder is absorbed or transmitted. Dense bodies and particularly those with smooth or light-colored surfaces, reflect light most perfectly, and any surface which reflects light well is called a mirror. There are three general classes of mirrors known as plane, concave, and convex. It is more particularly with the concave mirror that we shall have to do.

When light falls upon a plane reflecting surface, it is a well-known law that the angle of reflection is equal to the angle of incidence. If the reflecting surface be concave or convex, the same law holds good.

The same law might be illustrated with either a concave or convex mirror. A mirror only changes the direction of the rays of light which fall upon it without altering their relative position; that is if they fall upon it perpendicularly, they will be reflected perpendicularly; if they fall upon it obliquely they will be

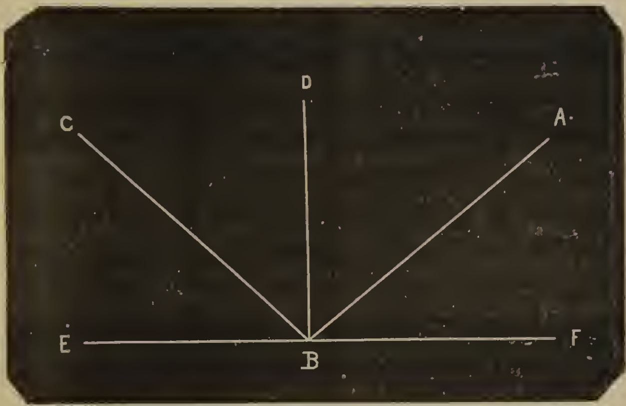


FIG. 1.

In Fig. 1 let A B be the direction of the incident ray of light, falling on a mirror E F. It will be reflected in the direction B C. Let D B be perpendicular to the surface of the mirror at the point of reflection B, and it will be found that the angle of incidence A B D is equal to the angle of reflection C B D.

reflected obliquely; or as optically expressed, the angle of reflection is always equal to the angle of incidence.

A concave mirror may be regarded as the interior surface of a portion or segment of a hollow sphere. When parallel rays of light fall upon the surface of a concave mirror, they are reflected and caused to converge to a point about half the length of the radius from the surface of the mirror. This point is called the principal focus of the mirror; and divergent rays issuing from it will be reflected parallel. Besides the principal focus a concave mirror has what are called conjugate foci. If the luminous point is at the center, the conjugate focus is at the center; if between the principal focus and the center, the conjugate focus is beyond the center; if beyond the center, the conjugate focus is between the principal focus and the center.

The principal focus of a convex mirror lies as far behind the reflecting surface as in concave mirrors it lies before it. With such a mirror parallel rays are rendered divergent and no real focus is formed. It is only by producing the divergent rays by imaginary lines on the opposite side of the mirror, that the principal focus is found. The focus in this case is called the virtual focus, because it is only an imaginary point toward which the rays of reflection appear to be directed. The terms negative and virtual are applied to the focus

of the convex mirror in contradistinction to the focus of the concave mirror which is positive and real.

Rays of light proceeding from several points of an object form what is known as an image. The images formed in a common looking-glass are mainly produced by the reflection of rays of light from the metallic surface attached to the back of the glass, and not from the glass itself.

We always seem to see an object in the direction from which the rays enter the eye; a mirror therefore, which changes the direction of the rays proceeding from an object, will change the apparent place of the object. Images are formed at the foci of concave mirrors, and by varying the distance of the objects before the surface of the mirror, we may also vary the position and size of the images formed at such foci. When an object is farther from the surface of a concave mirror than its principal focus, the image will appear inverted; but when the object is between the mirror and its principal focus, the image will be upright, behind the mirror, and increased in size in proportion as the object is placed nearer to the focus.

Let us now briefly consider what is meant by refraction.

Light, in a perfectly uniform transparent medium, traverses a straight line; but when light passes

obliquely from one medium into another, or from one part of the same medium into another part of different density, it is bent from a straight line, or refracted. A ray of light falling perpendicularly upon a surface separating two media continues in its original course. When light passes obliquely from a rarer to denser medium, it is refracted toward a perpendicular to the surface; but when light passes obliquely from a denser to a rarer medium, it is refracted away from a perpendicular to the surface. The amount of refraction varies with the medium and the obliquity of the rays.

No law has been discovered to enable us to judge of the refractive power of bodies by their other qualities, but as a general rule, dense bodies have a greater refractive power than those which are rare; but it may be well to mention that all highly inflammable bodies such as oils, diamond, phosphorus, amber, etc., have a refractive power many times greater than that possessed by non-inflammable substances of equal density.

When a ray of light passes through a transparent medium whose sides where the ray enters and emerges are parallel, it will suffer no permanent change of direction or refraction, since the second surface equally compensates for the refractive effect of the first; but if the surfaces of the medium are not parallel, the direc-

tion of the ray passing through is permanently altered; and the change is greater as the inclination of the two surfaces is greater. Such is the case when light passes through a prism. Rays of moderate obliquity are refracted toward the base of a prism. This last fact is important, for by it the laws of refraction by curved surfaces can be better understood.

FIG. 2.

Place two prisms base to base, (Fig. 2,) then any two parallel rays E E falling upon the surfaces at corresponding points will be equally refracted toward the base, and will necessarily meet and cross at some point C situated on the opposite side. This point is termed the focus of the rays.

Precisely this same thing would occur if the surfaces of the prisms were equally curved from center to edge, for all curved surfaces are composed of small plane surfaces arranged in a regular order corresponding to the curvature. A double convex lens may be regarded as two prisms with curved surfaces, united at their bases. When the surfaces of a double or bi-con-

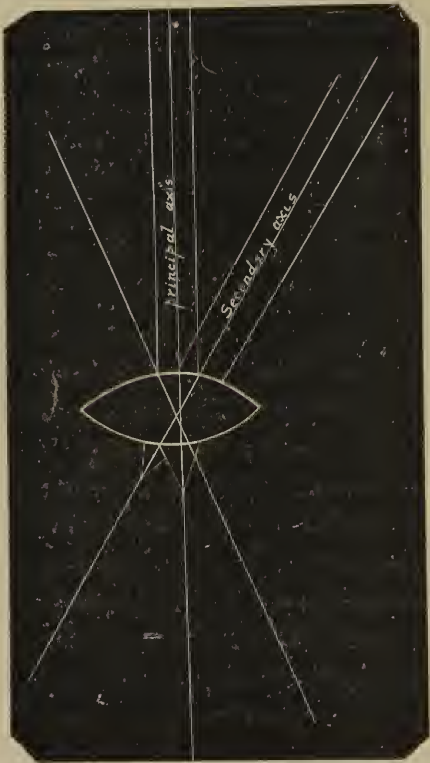


FIG. 3.

(Fig. 3). A straight line passing through the center of a bi-convex lens and perpendicular to both surfaces, is called the principal axis. Oblique lines passing through the center are called secondary axes.

vex lens are segments of a sphere, the lens is called spherical.

All rays of light except those corresponding with principal and secondary axes, are refracted. Parallel rays are brought to a focus in a point on the axis to which they are parallel, and the focus of such rays is called the principal focus. The principal focal distance is the distance of the principal focus from the optical center of the lens. For the sake of brevity, this is often called the focal distance, or focal length, of the lens.

CHAPTER II.

REFLECTION, REFRACTION, AND THE FORMATION OF IMAGES, (CONCLUDED).

Diverging rays from a luminous point situated at the principal focus are made parallel on passing through the lens; but rays from a more distant point being less divergent, are rendered convergent. The distance of the luminous point will determine the degree of the convergence of the rays, and as well, the distance from the lens of the focus in which the rays meet.

The closer the luminous point approaches the principal focus, the farther will the focus of the rays recede from the lens.

If the luminous point is carried between the lens and its principal focus, the rays after passing through will still be divergent, and no real or positive focus be formed.

Since convex lenses collect and concentrate diverging rays of light at a point called the focus, they consequently produce increased light and heat at this point. In like manner concave mirrors by causing divergent rays to become convergent, produce the same effect. But the chief use of lenses is to produce images, and

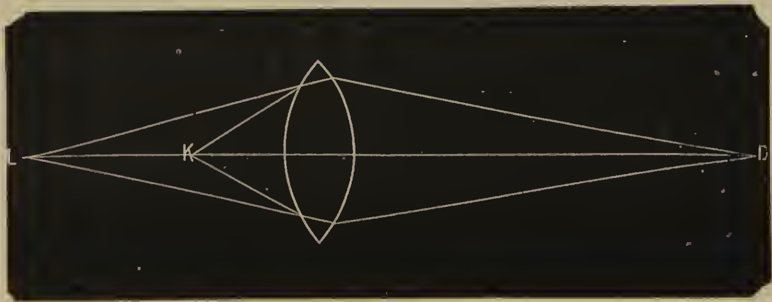
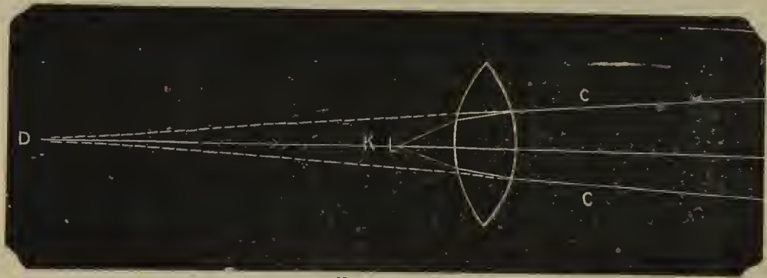


FIG. 4.

In Fig. 4 let L be the luminous point and K the principal focus of the lens. The diverging rays from L meet in D. The nearer L approaches K, the farther D will recede and *vice versa*. Place L at K, and the rays from it will emerge from the lens parallel. The points L and D bear a constant relationship to each other, and are interchangeable; they are therefore termed conjugate. They are both real and positive.



FIG, 5.

In Fig. 5, L is the luminous point, while K is the principal focus. If the lines C C be produced backward, they will meet in D and would have the same optical value as if they really came from D instead of L.

D is the conjugate focus of the luminous point L, but as it has no actual existence, it is virtual and negative.

images are formed in the foci of convex lenses in the same way as in the foci of concave mirrors. Convex lenses magnify the apparent size of objects seen through them. The reason for this is plain; for the lenses change by refraction the direction of the rays of light proceeding from an object, and they enter the eye as if they came from points more distant from each other than is actually the case.

This and other allied points will be made plain by a study of Figs. 6 and 7.

The distance at which a lens is held from an object modifies the size and the position of the image formed. This is demonstrated in Fig. 8.

With a convex lens of two or three inches focus one can easily illustrate the truth of the statements in Fig. 8. It should be remembered, however, that while the lens is at more than its principal focal length from the object, the inverted image is on his own side of the lens. It will appear to be upon the back of the lens.

This inverted aerial image is constantly used in ophthalmoscopy. Its careful study and thorough comprehension is essential to the practical mastery of the indirect method.

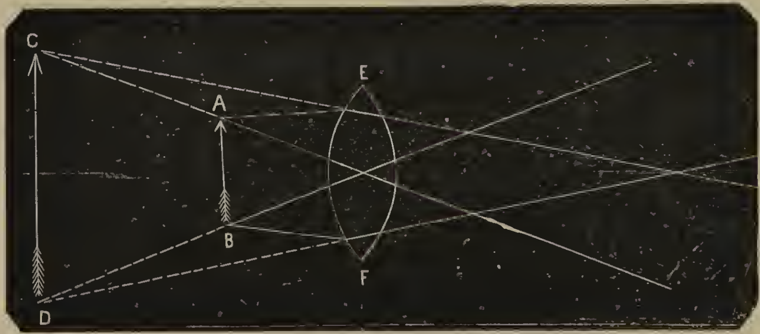


FIG. 6.

(Fig. 6). Hold the convex lens E F at less than its principal focal length from the object A B, and upon looking through the lens the enlarged image C D will be seen. The rays from the point A emerge from the lens divergent and have the optical value of coming from C. In like manner, rays from B appear to come from D.

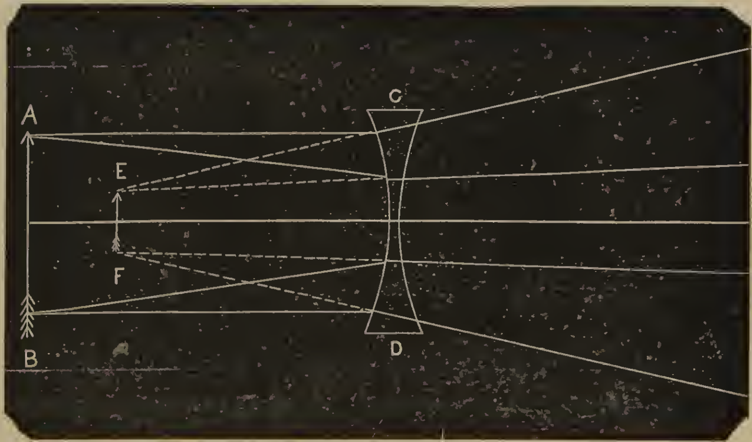


FIG. 7.

Fig. 7 shows how concave lenses produce a contrary effect, diminishing the apparent size of objects seen through them. Rays of light from the object A B on passing through the double concave lens C D are refracted outward. If reproduced backward, they would come apparently from the direction of EF, or from points nearer together than is actually the case. To the observer looking through the lens, the apparent size of the object is diminished.

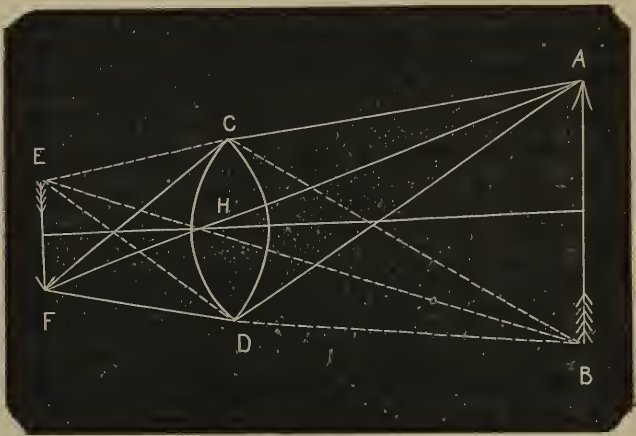


FIG. 8.

In Fig. 8 let A B represent an object beyond the principal focus of the lens C D. Tracing all the rays which pass through the lens from the point A, we find them uniting at F on the secondary axis A H F. All the rays from B which pass through the lens unite at E on the secondary axis B H E. In like manner each point in the surface of A B looking toward the lens, has its corresponding point imaged in E F, and E F is the inverted, diminished image of A B. E is the conjugate focus of B, and F is the conjugate focus of A; and varying the distauce of A B from the lens will cause these foci to advance or recede. It is only when the object is at a distance of more than double the focal length of the lens, that the image is diminished below the size of the object, and the diminution is greater as the object is carried farther away. If the object is held

at just double the focal distance of the lens, the image will be at the same distance from the lens as the object and of the same size. Bring the object nearer and the image recedes and increases in size until the object reaches the principal focus, when the image disappears. The image disappears because the rays emerge from the lens parallel, thus producing diffuse light. Carry the object within the principal focus, and the emergent rays will be divergent. If these rays are traced backward, they form a negative focus on the same side of the lens as the object. Hence there is now produced an erect, virtual, magnified image of the object in the position of the negative focus.

CHAPTER III.

THE THEORY OF THE OPHTHALMOSCOPE.

The eye itself is an optical instrument in which the refractive media combined are about equal to a convex lens of one inch focus. By means of these media, images of external objects are formed upon the retina in an inverted position. In a normal and healthy eye, images of objects at various distances are distinctly focussed upon the retina, although it is evident such would not be the case without some change in the refractive power of the media. A change takes place which is called the accommodation of the eye.

By its accommodative power, the eye adjusts itself involuntarily for perception of objects at distances varying from a few inches to about eighteen to twenty feet, which is regarded as infinity. Divergent rays from near objects and parallel rays from distant objects, are just as accurately focussed by a simple change in the focal distance of the lens, (in a manner as yet in some obscurity, different theories being advanced and seemingly well sustained by their authors), in conjunction with other changes not necessary to consider here.

As has been stated in the introduction, it was form-

erly believed that rays of light entering the eye reached the fundus and were there absorbed by the pigment layer of the choroid; hence no rays were reflected outward through the pupil to convey to the eye of the observer an image of the interior. This belief seemed confirmed by the black appearance of the pupil. The reason for such a mistake was due to the fact that rays of light projected into the eye are returned to the point whence they came. By means of the refractive media the ingoing and outcoming rays form a cone of light whose base is at the pupil, and whose apex is at the source of illumination. This cone of light is nowhere wider than the pupil and diminishes in width as the distance from the pupil increases. It is therefore evident that any attempt of the observer to place his head so as to receive the emergent rays within his own pupil, would cut off the whole source of illumination; for the width between the observer's pupil and the temporal side of the head is much greater than that of the cone of light at any point.

By the simple contrivance shown in Fig. 9, the difficulty is overcome. This cut correctly illustrates the original contrivance of Helmholtz, the discoverer of the Ophthalmoscope, except that the plane C D was of solid superimposed plates of glass.

A plane mirror, C D, receives the rays of light from

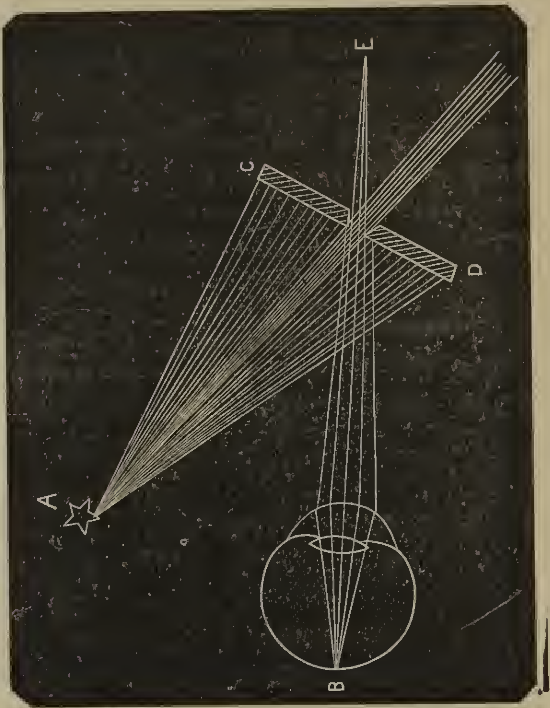


FIG 9.

the luminous point A, and reflects a portion of them through the pupil of the eye under observation. They are focussed at B on the retina, and being reflected outward again, a portion passes through the hole in the mirror in the direction of E. This is a simple form of the Ophthalmoscope, and the eye of the observer at the sight hole behind the mirror receives the rays from the fundus.

The emergent rays from the fundus are generally slightly convergent. They may be rendered parallel by either placing behind the mirror a concave lens, with which all instruments are supplied, or by requiring the patient to look at a distant object, the latter way being used as experience permits.

By looking at a distant object, the eye is accommodated for parallel incident rays, hence the emergent rays being equally refracted become parallel. Parallel rays are better adapted to the formation of distinct images upon the retina of the observer.

Ordinarily the concave mirror is preferred to the plane. By concentrating the incident rays, it not only reflects more light into the eye, but as the rays are convergent when they enter, they are brought to a focus before reaching the retina, and as a result cross each other and form circles of dispersion. A larger portion of the fundus is thereby lighted up at one time.

In Fig. 10 we have a diagram illustrating what is known as the direct method of using the Ophthalmoscope, or examination with the plane or concave mirror alone.

A is the source of illumination, from which rays impinge upon the concave mirror with its sight-hole B. They are thence turned into the eye. Let cc represent the circle of dispersion formed on the retina by the rays crossing in the vitreous humor. The return divergent

FIG. 10

rays from any point t would emerge parallel and have the value of rays coming from the direction ee at points behind the eye, and from any point s the value of rays from dd; hence the eye of the observer placed at B sees an enlarged, erect, virtual image situated apparently behind the eye observed.

It will be seen that this form of the Ophthalmoscope is very simple and consists in substituting reflected light for direct light, and in taking advantage of the return rays which pierce the hole in the mirror.

In Fig. 11, is shown what is known as the indirect method of examination, consisting in interposing the double convex lens A, of from two to four inches focus, and holding it near to the eye to be explored.

This lens renders the rays from the mirror more convergent and they are again converged by the crystalline lens of the eye and form very large circles of dispersion upon the retina; thus a large portion of the eye is lighted up. Again, the rays emerging from the eye are brought to a focus between the interposed lens and the mirror, and form a well-defined inverted image in the air. The size of this image depends upon the focal length of the lens; the greater the focal length, the larger the image. The lens B behind the mirror is used to magnify the inverted image. Other lenses may also be used behind the mirror, if the eye of the observer is not emmetropic. The lens B should have about eight or ten inches focal distance.

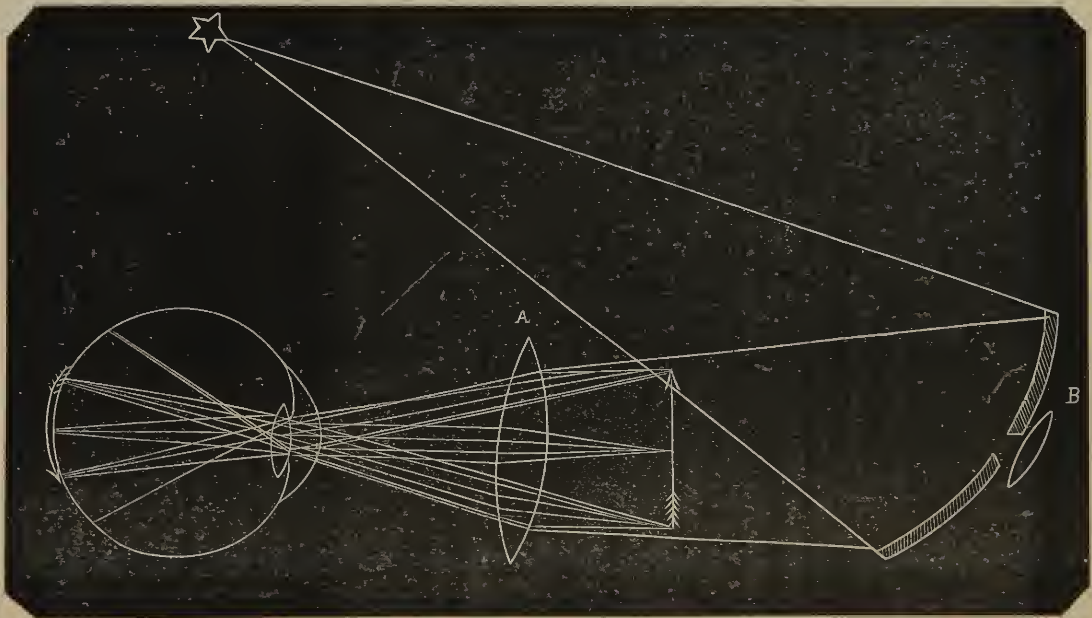


FIG. II.

Embraced within these two methods will be found all the optical problems which have been considered heretofore. If clearly understood, the remainder of the subject is readily grasped; but if any point be dim, the reader is recommended to go back and rectify the error before proceeding farther.

CHAPTER IV.

DESCRIPTION OF DIFFERENT INSTRUMENTS.

There are many modifications of the Ophthalmoscope devised by ingenious brains to develop and clear up the seeming difficulties, but all involve the same principle. An examination of their mechanism with a careful study of their advantages will render the modes of use quite plain, and familiarize the examiner with the details of the practical principles involved. This, however, will not be attempted here, but those of Knapp, and Loring, of New York, be considered, as being not only those most likely to be used, but as the best with which I am acquainted.

Although by the inventor considered as not to be so highly recommended as his single-disc instrument, Knapp's double-disc Ophthalmoscope so clearly illustrates the principles upon which the instruments using the disc of Rekoss, (the revolving disc carrying the little lenses), are constructed, that a carefully compiled summary of it will be given as typical of the mechanism of the rest. It is taken from the inventor's description in the *Archives of Ophthalmology and Otology*.

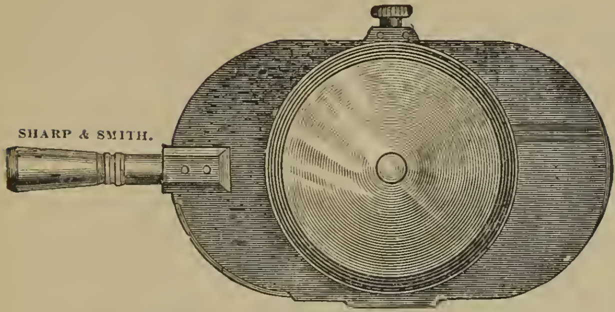


FIG. 12.

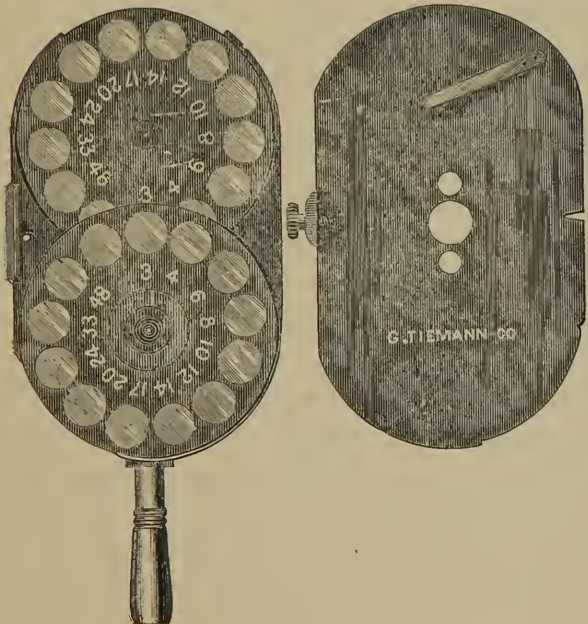


FIG. 13.

Fig. 12 shows the front view, and Fig. 13 the back view with the cover removed and placed to the right side.

"Its reflector in the ordinary concave mirror, as in Liebreich's and other instruments. It is screwed on a thin plate of metal. On the other side of the metal plate lie two discs, of which the upper contains the convex lenses, 2, 3, 4, 6, 8, 10, 12, 14, 17, 20, 24, 33, 48, and the lower a like series of concave lenses.

"Each disc rotates on a central pivot, and presses upon a delicate spring having at its end a small point-like elevation. Oppposite each lens is a point-like depression, into which the spring falls when the disc is rotated. These depressions are not so deep, however, as to prevent the disc from being easily turned, yet deep enough to cause the arrest of the disc when the center of the auxiliary lens through which we want to look, is just opposite the center of the aperture in the mirror.

"The margin of the lower disc overlaps the margin of the upper in such a way that each positive glass can be covered by each negative glass, and the reverse. Thus combinations are formed which enable us to obtain a very extensive series of test-glasses.

"The rotation of the discs is very easy. When the instrument is closed, the margin of the upper disc pro-

jects over the upper edge of the metal plates, whereas the margin of the lower disc projects on both sides over the lower end of the plates. Each disk can be rotated to the right or left by a slight touch of the finger. This arrangement enables us to change the glasses without removing the instrument from the eye.

"The lower disc is rotated with the forefinge of the hand which holds the instrument, whereas the upper disc is turned with the forefinger of the other hand.

"The cover has three round apertures. The larger central one is opposite the aperture in the reflector, and serves for the passage of rays of light from the eye examined into that of the physician. The correcting lenses, when used, lie between this central aperture ot the cover and the aperture of the reflector. In order to know what lenses are used, two smaller round openings are placed one above the other, below the central aperture of the cover. Through these smaller apertures we read the numbers of the auxiliary lenses which are behind the opening in the mirror. Whether these lenses are positive or negative, is indicated by the plus and minus signs placed near the smaller apertures.

"A short ivory handle screws into a brass socket fastened to the mirror, and two larger lenses (plus 2 and 3, or other numbers according to the pleasure ot the physician) are added.

"Commonly the examination is begun without any auxiliary glass, namely for the investigation of the refracting media. After that the fundus is explored in the inverted image. Nearsighted observers do this without an auxiliary glass, but emmetropic, presbyopic and hyperopic observers are in the best optical conditions by placing a convex glass behind the mirror, thus rendering themselves artificially myopic, which should be of the degree of about 1-8 or 1-10 the ordinary visual distance for looking at fine objects. I have always been in the habit of placing plus 10 behind the mirror, and using plus 3 as the objective lens. This is a very convenient combination and magnifies the inverted image to about three-quarters of the diameter of the erect image."

The various auxiliary lenses represented in each disc are made to subserve two chief ends, viz., the determination of ametropia by the objective method, and the measurement of elevations and depressions in the fundus of the eye. The first is fully considered under myopia, hypermetropia,* etc.; the method of calculating the latter will be given in the chapter on Ophthalmoscopic Optometry (XIV.)

If the observer himself is ametropic, he is recom-

* The ascertaining of ametropia by the subjective method, or by the use of "trial-" or test-glasses," is fully expounded in the author's monograph on "Spectacles; and How to Choose Them."

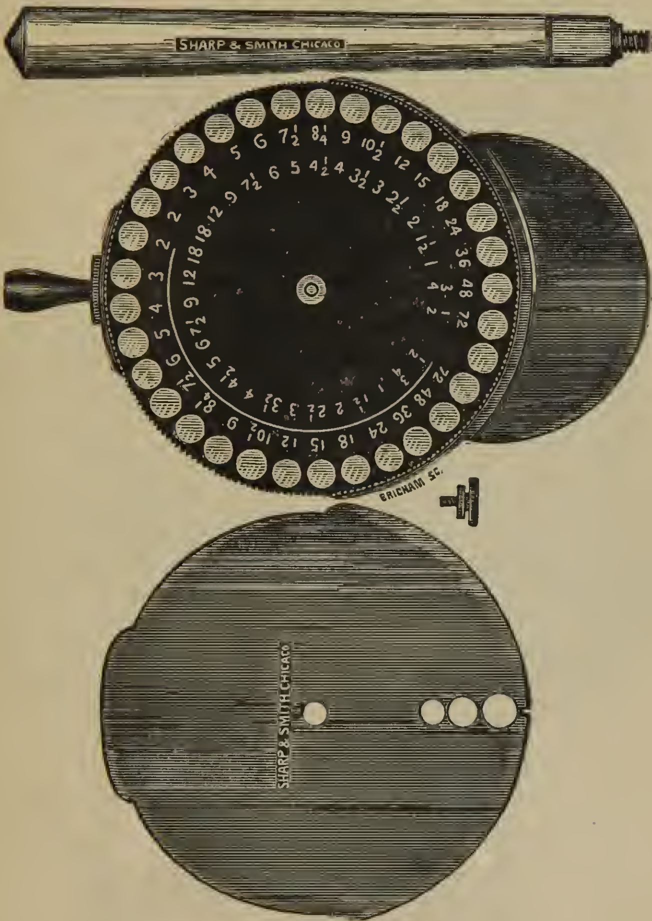
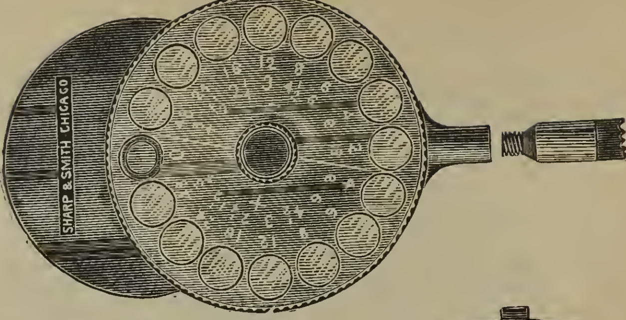
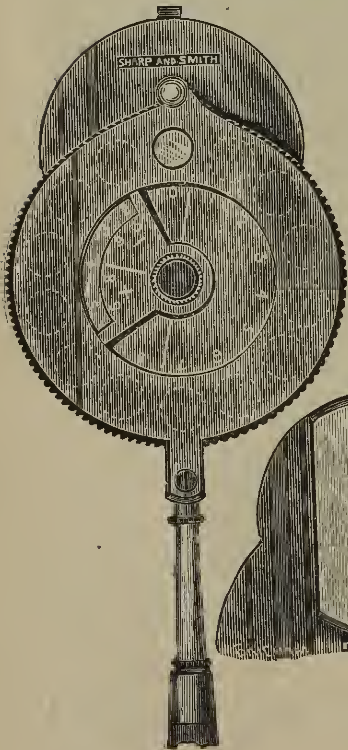
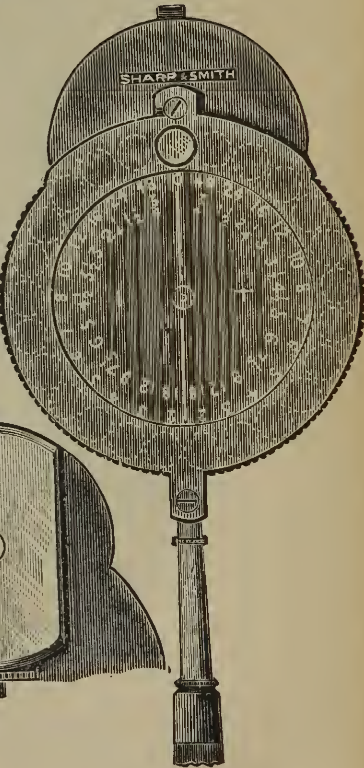


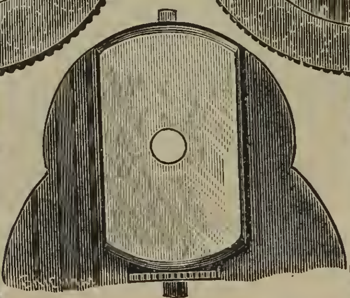
FIG. 14.

mended to have the lens which corrects his ametropia inserted in each disc, unless one disc already contains a


SHARP & SMITH CHICAGO


SHARP AND SMITH


SHARP & SMITH



lens of the number required, in which case its counterpart only need be inserted in the other disc.

By combining a positive with a negative glass of different power, there results a lens whose refractive power is equal to the difference between the powers of the lenses used. It is obvious that the resulting lens will be positive if the positive glass is stronger, and negative if the negative glass is stronger. With these glasses a large number of combinations can be made.

In Fig. 14, there is shown Knapp's single-disc Ophthalmoscope. In a letter received from the inventor, it is described as "a single disc of 5cm. in diameter, with thirty lenses, centered and covered, the hole of the mirror 3.5mm. in diameter. The series of glasses is 0, plus 72, 42, 36, 24, 18, 15, 12, 10, 9, 7, 6, 5, 4, 3; and the same negative series with the addition of minus

"The construction is like that in the Ophthalmoscopes with 24 and 33 lenses. The inches are marked above, the dioptries below."

Opposite is the representation of Loring's instruments. The uppermost one is that of a back view of his student's Ophthalmoscope; the one on the right, the same of his single disc; on the left, the same of his double disc. The lower central cut represents the "tilting mirror," the peculiarity of his later instruments.

A description of his double-disc instrument, mainly abridged from the Transactions of the American Ophthalmological Society, 1878, is as follows:

It consists of a single disc and a segment of another disc. The single disc contains sixteen glasses, from 1 to 7 D (dioptries) plus, and from 1 to 8 minus, with an interval of one D, which is considered sufficient for all ordinary purposes. If, however, higher numbers are desired, or smaller intervals (0.5 D), these are obtained by means of the quadrant, which contains four glasses plus 16 D, minus 16 D, and plus 0.5 D, and minus 0.5 D, which can be brought round and applied over the glass of the disc behind the hole in the mirror. Thus, with the superposition of a single glass (plus 16 or minus 16) and with an uninterrupted rotation, a series is obtained of successive dioptries from 1 to 23 plus, and from 1 to 24 minus, and a half series with the addition of the 0.5 D from 0.5 to 8 plus, and from 0.5 to 9 minus, or sixty-five glasses in all.

The value of the glasses and the combinations is read off on the disc by a method peculiar to the instrument. This consists in having two concentric rows of figures, the outer of which shows the real value of the glass, and the inner the result of the combination when the supplementary glass is over the hole of the mirror. As the plus glasses are in white and the minus in red,

and as the outer row is shut off when the inner is opened, no possible confusion can occur. Should the combination not be wanted, a trifling displacement of the quadrant to either side of the mirror hole at once dissolves it, and the instrument becomes a single disc Ophthalmoscope.

The mirror of the instrument is Loring's "tilting" mirror, which is a modification of the old mirror, obtained by cutting off the sides of the ordinary concave mirror, producing thereby a parallelogram 18mm. in diameter, and 34mm. in length. "The idea was suggested by Wadsworth's small circular mirror. Unlike this, however, it is designed for both the upright and inverted image, thus obviating a change of mirrors, it being found that abundant light is obtained for both methods. The mirror is swung on pivots which allows a tilting to either side of about 25 degrees. By this means the inclination of the correcting lenses is avoided, by which a large quantity of light is saved, and the image rendered free from distortion."

The inventor lays great stress on this peculiar tilting as a very necessary adjunct for all who wish to make an easy and accurate examination by the direct method.

A brief comparison of the excellencies and aefects of these, and other instrumens, wil be found in the next chapter.

CHAPTER V.

DESCRIPTION OF DIFFERENT INSTRUMENTS (CONCLUDED).

It being an almost hopeless task to enumerate the names even of those who have invented Ophthalmoscopes, those to be first recommended have been designated in the preceding chapter. As in other inventions the inventor has been greatly aided if not surpassed by contemporaries in the execution of mechanical details, so with the Ophthalmoscope. Much may therefore be gained by a glance at a few of the best known manufactures. *

Of the instruments commonly selected by a novice, that of Liebreich, represented in Fig. 16, is undoubtedly oftenest chosen. Probably this is largely the case because it is the cheapest. It is, however, nearly always too cheaply made for accuracy, and too limited in its range for the highest classes of ophthalmic work. The auxiliary lenses, few in number, are packed in the box with it, as illustrated in the cut.

*Carter in his work on Diseases of the Eye (American Edition, Green, p. 147,) writes that Charriere, of Paris, has formed a museum of forgotten eye-instruments. I called to see it, hoping to find among the other instruments a collection of Ophthalmoscopes, but was informed that no such collection had ever been made.

Jaeger's, Fig, 17, as modified by Schnabel, Hirschberg, and others, mainly holds the field abroad, and very justly; it is being somewhat superseded in consequence

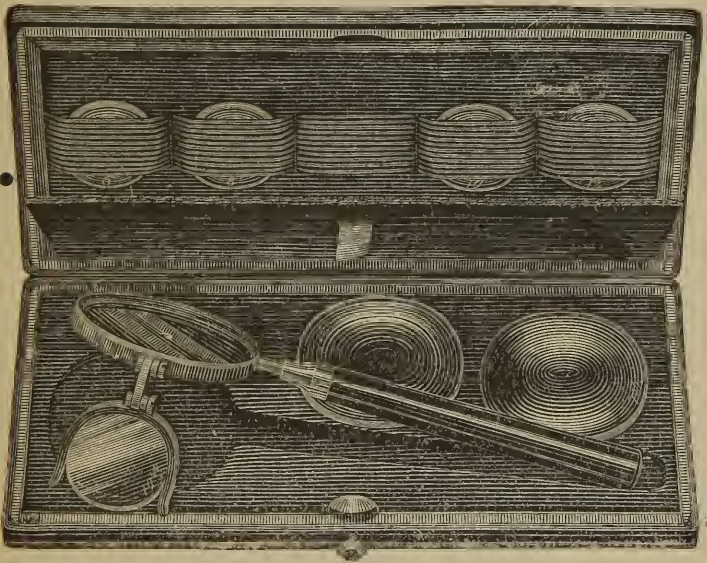


FIG. 16.

of the at least superior workmanship of the American inventions. Its great advantage is that it allows the mirror to be inclined independently of the correcting glasses, (as does Wadsworth's, Loring's, etc.,) so that the observer always looks through the lenses in the direction of their axes, thus avoiding the apparent astigmat-

ism which results from their inclination, and permits of the light being placed over the head of the patient. In this latter peculiarity, it has few competitors.

Nachet's Fig. 18, is a handy little affair to catch

FIG. 17.

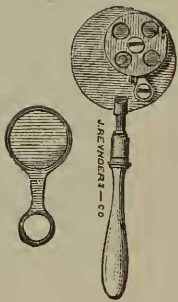


FIG. 18.

glimpses; its main claim to use rests on the fact that it can be put in the vest pocket.

Landolt, who has given us much advice on this and kindred subjects, has given us an Ophthalmoscope of his invention. The claims for it rest on a smaller disc and larger lenses than most other instruments, combined with a peculiar method of reading the combinations

without difficulty. The lenses are plano-spherical, their plane surfaces being applied to each other.

Wadsworth, Couper, Noyes, Badal, Baumeister, Wecker, Galezowski, and many others have added to and taken away from existing Ophthalmoscopes, as well as invented more or less new portions, but all have used the concave mirror.

Zehender's Ophthalmoscope may be taken as a sample of those with a convex mirror. This instrument consists of a convex mirror with a radius of curvature of 16 centimetres. The mirror has a funnel-shaped perforation at the centre; "at the sides of the mirror are two flexible arms, one of which holds the correcting glass while the other carries a convex lens of 13 dioptries having about the same diameter as the mirror. The observer gives to this lens such an inclination that it concentrates the light from the lamp at the side of the patient on the mirror. The arm holding the lens is adjusted to the side of the mirror next to the light, to the right or left, as the case may be."

Ophthalmoscopes have also been devised with plane mirrors, prismatic mirrors, and silvered lenses or menisci.

From the array of distinguished names, the owners of which have lent their talents to the perfection of this instrument, it would seem that the subject would

be thoroughly exhausted, and as near perfection as is possible attained. But it must be remembered that "strict philosophical precision and practical utility are two different things."

The demonstrating Ophthalmoscope deserves mention as an instrument devised for the purpose of aiding the learner of ophthalmoscopy early in his study of the subject. It can hardly be called useful, after a person has become skilled, except it be for the purposes of teaching. The form of the instrument devised by Mr. Carter is one of the best, and I cannot do better than to describe it substantially in the author's own words.

Mr. Carter says: "A variety of demonstrating Ophthalmoscopes have been devised, each intended to be so adjusted by a skilled person, that one who is unskilled may be able to look into the instrument as he would into a microscope, and to see the optic nerve and retina. These demonstrating Ophthalmoscopes are all designed to show the inverted image, and they all labor under the same serious disadvantage, namely, that although, in studying the inverted image, it is constantly necessary to move the mirror and lens independently, yet these parts are so connected, by some kind of tube or bar that the readjustment of one implies the derangement of the other. In some even the lamp itself is attached to the instrument; and, in others, rods or

stems project from the tube, and rest on the forehead of the patient, whose slightest move will put everything out of gear. To obviate these inconveniences, I devised my own demonstrating Ophthalmoscope, starting with the principle that every part of it should be absolutely independent of every other part, and capable by itself of quick and easy adjustment. For this purpose the mirror and lens are placed upon separate pedestals; a similar pedestal supports the chin of the patient, and they all stand upon a table which also carries a lamp, and on which they may be moved freely. My first trials with this arrangement satisfied me that it would work better than any other; and also showed that it could be made to afford an image of greater enlargement than any other, as well as a brighter illumination. It has already been pointed out that the greater the focal length of the object lens the greater will be the size of the image; but the limits of enlargement thus attainable by hand instruments are soon reached, and an object lens of greater focal length than three inches is not available in practice. The object lens gives the best results when it is held at its own focal length from the cornea of the patient, and while this is done it is very desirable that an extended finger should touch his orbit, and thus steady the hand. In this direction, therefore, the focal length of three inches cannot be exceeded;

while on the side of the observer, there is a limit imposed by the length of the arm. A lens cannot be held steadily and comfortably when the arm is fully extended, nor at more than twenty inches from the eye of the observer; and if the image is formed much within this distance there is but little left for his visual range. But by using a table we are rendered independent alike of the steadying finger and of the length of the arm, and may increase the distance between the patient and observer without limit. I therefore use an object lens of eight inches focal length, which gives a very large image, sixteen inches from the eye of the patient; and I place my mirror forty inches from the eye of the patient, which gives a visual distance of twenty-four inches for the observer."*

"In order to obtain sufficient illumination, the lamp is brought up from its usual position, and is placed nearly in the focus of the mirror, while the face of the patient is guarded from direct lamp-light by the interposition of a metal screen. For use without Atropine,

*"In Mr. Carter's demonstrating ophthalmoscope the place of the inverted image is greatly influenced by the refractive condition of the eye under examination. It is only when the examined eye is of normal refraction that the image is formed at the focus of the object lens; in myopia exceeding one-eighth the image lies between the examined eye and the lens; while in hypermetropia the power of the object lens may be inadequate to the formation of an image at any useful distance. This constitutes a defect which may, however, be overcome in a great measure by having stronger object lenses for the different grades of hypermetropia."

and in order to avoid contraction of the pupil, a plate of glass slightly tinted with cobalt blue, is interposed between the flame and the mirror. This filters out, so to speak, the yellow rays, which are the most irritating, and leaves only a soft blue light, which the most sensitive eye can bear without distress. The best, because the whitest and purest light, is that furnished by the Silber Argand burner consuming either gas or oil; and it should be so arranged in any case as to be capable of adjustment to any height that may be desired. Any good burner constructed on the Argand principle will answer."

With all the instruments described, the observer can employ but one eye at a time while making observations. In order that he may obtain the advantage of employing the vision of both eyes, an instrument called a binocular Ophthalmoscope has been devised. That binocular vision has advantages over monocular is well known. With both eyes, inequalities of surface, excavations, tumors, etc., can be readily made out, and their extent determined. The binocular Ophthalmoscope, although ingenious and sometimes useful, is not commonly employed owing to its being less easily adapted to the work that the simple monocular instrument. Experience in using the latter goes far toward

compensating for qualities which it does not possess, and renders the former wholly unnecessary.

Fixed Ophthalmoscopes, provided with means of supporting and adjusting the patient's head in desired positions; aut-ophthalmoscopes, by means of which a person with one eye may examine the fundus of his other eye; and those permitting two or more observers at the same time, are forms of instruments which may be mentioned as interesting but not essential.

We may conclude our glance at the different Ophthalmoscopes with the following deductions:

It is essential that in all instruments the eye-hole be not less than three millimetres in diameter, otherwise it will act as does a stenopæic apparatus in improving the vision.

An oblique mirror aids the beginner to command the erect image much sooner than the ordinary concave mirror; hence, in this respect at least it must be an advantage; and the instruments with it (Jaeger, Loring, etc.,) have an advantage in this respect over those without it.

When the correcting glasses are too small, part of the light employed goes to dazzle the patient without contributing to the brightness of the retinal image under examination. This is because the brightness of an object, though not essentially interfered with when

seen through a fair-sized glass lens, rapidly diminishes as the diameter of the lens becomes less than that of the image of the pupil as formed by the corneo-aqueous system.

The light used for illumination ought to be behind the head of the patient, to prevent the inconvenience of the heat; for the oblique incidence of the light is lessened in proportion as the illuminating flame is placed nearer to the straight line between the centers of the observed and observer's pupils.

Although experience goes far toward correcting inherent defects in any instrument with which we become familiar, all instruments with a flat revolving (Rekoss) disc, and the ordinary concave mirror, (Knapp, Landolt, etc.,) having the focal distance of their lenses in such disc calculated for vertically impinging light, must change and shorten the same by the necessary oblique position to sufficiently illuminate the pupil. In this respect, they are at a disadvantage as compared with those which permit of an inclination of the mirror separate from the disc (Jaeger, Loring, etc.).

That such a disadvantage is not a very serious one is readily admitted. I have used one of Knapp's for years with great satisfaction.

Yet, the astigmatism increases with the strength of the lenses, rendering in the case of the higher powers a careful and exact estimation impossible. Further-

more, "the astigmatic distortion of the image, which is induced by an oblique position of the stronger glasses, impedes the sharp distinction of the minuter details and interferes with the objective diagnosis of an existing astigmatism."

CHAPTER VI.

THE PRACTICAL APPLICATION OF THE OPHTHALMOSCOPE.

A skillful operator can obtain in most eyes a very good idea of the condition of the fundus without the use of a mydriatic. It is usually quite unnecessary in cases where it is only desired to examine the optic disc and its immediate vicinity. In such cases, care should be taken to use a moderate degree of illumination only; a bright light causes contraction of the pupil, and dazzles the eye of the patient to such an extent that it is almost impossible to relax the accommodation.

When it is found necessary to dilate the pupil, a solution of the pure neutral atropia sulphate, of the strength of one grain or less to the ounce of pure water, should be used. Put one drop of this solution in the eye to be examined, and wait until the pupil is dilated. Generally but one pupil should be dilated at a time, and the weaker the solution of Atropine employed, the less inconvenience the patient will suffer from its effects upon the vision. In respect to time of dilatation, homatropine may be used to advantage. A solution of one to two grains to the ounce of distilled water will

dilate the pupil, and its effects be gone in about twelve hours. In all cases the patient should be told of its effect, and even then an ignorant one may blame you for "blinding his eyes." Such interference with the vision soon passes off however. If no Atropine be used, the dilatation of the pupil of the eye to be examined can be increased somewhat by bandaging the other eye, a course not to be recommended usually, since that eye is needed for fixation.

The Direct Method of Examination.—In Fig. 19 may be seen a position in which, unfortunately, many use the Ophthalmoscope, and a way I have seen recommended in ophthalmic literature.

It should be understood that this is not the best manner in which to use this instrument, and the beginner will do well to carefully observe the following directions, noting wherein they differ, both in the direct and indirect methods, from what may be seen in the figure.

The room should be darkened and the patient seated erect near a table, resting his arm upon the table to steady himself, or with his back firmly supported by a chair. A light with a clear steady flame, should be stationed to one side and about a foot behind the patient's head; it is better, but not essential, to be upon the side of the head corresponding to the eye to

be examined. Any good light will answer, and it is unnecessary to have any of the expensive or patented standards, though what is known as an oculist's bracket,

FIG. 19.

with a double-armed adjustable swinging movement, is very convenient.

The surgeon now seats himself opposite the patient, their eyes on a level, or nearly so, and this position is best attained by having one or each seated upon a re-

volving adjustable chair. The surgeon may use either eye for examination of one of the patient's eyes, but it is preferable to use the one corresponding to the one to be examined, that is the right for the right, and the left for the left.

Let him take the Ophthalmoscope in his right hand, if he is about to use his right eye, delicately holding it by the handle near its free end, and lightly resting the upper portion of the rim of the mirror against his brow while he applies his eye to the sight-hole. He should now momentarily close his companion eye to be sure he is looking through the sight-hole, and then keep both eyes open. The mirror must be so inclined to the light that the reflection will fall directly upon the patient's pupil. Having thus far followed directions, the pupil of a healthy eye will present a reddish appearance from the bright reflection of its fundus. The patient should now be directed to look slightly inward and fix his gaze upon some distant object over the surgeon's right shoulder, and about on a level with the tip of his ear. If his left eye is to be examined, he should look over the surgeon's left shoulder in the same manner. The reason for the patient's looking at a distant object has already been explained.

As soon as the eye is turned inward, the red appearance of the pupil changes to a light yellow, seemingly

white in persons of dark, swarthy complexions. This change is caused by the optic disc coming into view. The disc is usually the starting point in exploring the surrounding parts of the fundus, but before proceeding to a closer examination it is well to first ascertain from a distance with the Ophthalmoscope whether the red reflection of the fundus is clear. Some slight opacity of the lens or vitreous may thus be detected, and explain an appearance which would perhaps otherwise be referred to the fundus.

Next the surgeon should ascertain if the refraction is normal by observing if the retinal vessels can be seen clearly from a distance. If the vessels are distinctly visible at a distance, the eye is either myopic or hypermetropic; the first if the vessels move in an opposite direction from the observer's head when moved sideways, and the second if they move in the same direction. In emmetropic eyes, the details of the fundus can only be distinctly seen at a distance of two or three inches from the patient's eye, while in the other conditions, myopia and hypermetropia, the mirror must be held at a distance of about fourteen to sixteen inches. However, if an appropriate correcting lens is held behind the mirror, the emergent rays from the fundus of the patient's eye may be rendered parallel, and a clear image obtained at a short distance, the same as in em-

metropia. A concave correcting lens will be needed for examination of myopic eyes, and a convex for hypermetropic eyes. The power of this correcting lens will, of course, depend upon the degree of myopia or hypermetropia to be overcome. Furthermore, as there are usually unconscious efforts of accommodation in either the eye of the observer or of the observed, a ten or twelve inches concave correcting lens may be found useful in examining an emmetropic eye. These unconscious efforts in the eye of the examiner may also be overcome by experience, those of the patient by atroponization.

The direct method shows only a very limited field at a time. Seemingly the more simple, it requires much careful and patient practice for its mastery. Its importance will be made clearer farther on.

The Indirect Method of Examination.—This method, illustrated in Figure 19, requires the use of one of the large convex lenses in conjunction with the mirror. The lens of two and one-half or three inches focal distance is most commonly used. Following the manner laid down in the direct method as far as necessary, the surgeon then takes such a lens between the thumb and forefinger of his unoccupied hand and brings it up before the patient's eye from the outer (temporal) side, resting his extended little finger

on a spot near the temple to steady the hand. Not moving his little finger from its resting place, nor the Ophthalmoscope from his brow, he tells the patient to look slightly inward and observe some distant object, as in the indirect method, and at the same time adjusts the lens to its focal distance. The reflected rays from the mirror now pass through the interposed lens and enter the pupil. The mirror is held at some distance in all the conditions of refraction; for by the use of this lens the distinctions of myopia and hypermetropia and involuntary accommodation in the observed eye may be practically disregarded so far as searching for a distinct image is concerned. This image has been shown to be actually on the observer's side of the lens, inverted and in the air; and the observer's eye need only be moved a little nearer in myopia, and a little farther away in hypermetropia, in order to see it well. If the optic disc is only partly in view, it can be brought fully under observation by the surgeon moving either his head or the objective. The image moves in a direction opposite to the movement of his head, and in the same direction as the movement of the lens.

There may of necessity be some bending movements of the surgeon's body while properly adjusting the mirror, the objective, and his distance from the patient; but there is no necessity to crouch down, slide over the

chair seat and fumble the patient's nose or face, perhaps hitting his eyeball. Not only is it unnecessary, but it often alarms a young or timid patient, or disgusts one older and more confident. These points are not only urged because proper, but because essential to complete success. If the surgeon's body be screwed around, he will also perhaps get an imperfect view, and if he obscures the eye not under observation by bringing up the object lens from the nasal side, or by raising his elbow, or by making any awkward motion, the eye under examination will wander and prevent a perfect view.

An apt student will soon become able to easily move his head in various directions, all the while keeping the light accurately focussed upon the pupil. Not only should he become adept in this, but also in focussing a clear and sharply defined image of each detail.

The head of the observer must be at such a distance from the aerial image as is sufficient for the preception of small objects. The image may be enlarged with advantage by using a convex lens of about ten inches focus behind the mirror.

Lateral, or Oblique Illumination.—This method of examination may be employed with much benefit for parts of the eye as far back as the posterior lens capsule.

It is much used in conjunction with the Ophthalmoscope, hence its consideration here.

In Fig. 20, illustrating this method, the lamp is placed in advance and to one side of the head of the patient and the observer sits in front or stands behind

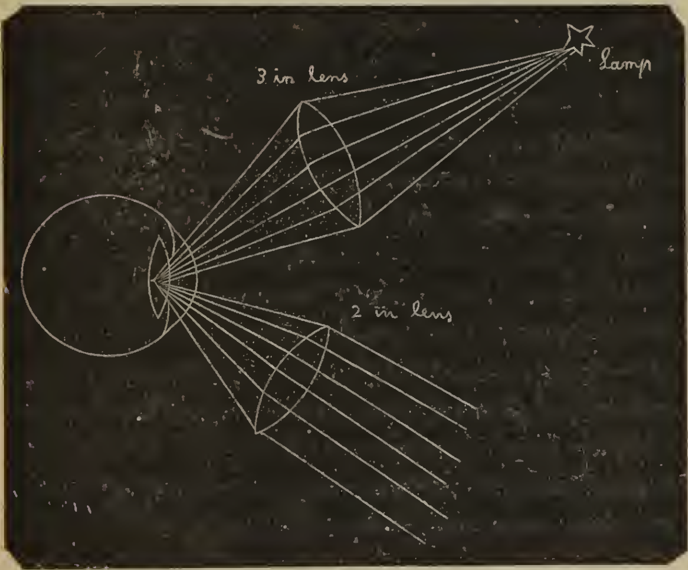


FIG. 20.

the patient. Either lens may be used to concentrate the light from the lamp upon the patient's eye, and the other lens used as a magnifying glass, if desirable, through which the observer looks at the parts under examination. Diffused daylight may also be employed. By successive movements of the patient's eye, occasion-

ally varying the position of the lens, the cornea, crystalline lens and iris may each be thoroughly examined. In the diagram the surgeon is supposed to be seated and viewing the eye through the 2 inches lens, the light being concentrated by the 3 inches lens.

All changes of the crystalline lens and parts anterior to it may be seen in their true colors, but with the Ophthalmoscope all opacities appear black. Foreign bodies, nebulæ, synechiæ, etc., invisible to the eye alone, may be easily defined by this method. The minutest facet or indenture on the cornea may also be detected by placing the patient with his face toward a window through which strong daylight is falling. Any such irregularity will at once become apparent by the seeming "shooting off," or dispersion of the rays from it, looking on a smaller scale not unlike a mirror indented and cracked by a sharp blow which causes the glass to splinter. It is best seen by looking in a direction nearly at a right angle to the course of the incident rays of light.

CHAPTER VII.

THE RELATIVE VALUES OF THE DIRECT AND INDIRECT METHODS, ETC.

The relative value of the direct and indirect methods has been the subject of much contention, often being the guiding point in the construction of a particular Ophthalmoscope, so much so that one may judge quite accurately which method the inventor preferred.

Unquestionably he who allows his prejudices to carry him to either side to the neglect of acquiring the whole subject, fails to excel in the use of the instrument. Both are so valuable that they should be thoroughly comprehended.

In support of the advantages of the direct method, I could do no better than to cite the argument of Prof. Hirschberg, of Berlin.

Whoever wishes to have a clear insight into the dioptric condition of an eye ought to view the retinal image which is formed by that eye as directly as possible, and that in most cases is the erect image, or in cases of extreme myopia the inverted, as seen without correcting glasses. For whenever a strong convex lens (of from

2 to 4 inches focus) is superadded to the dioptric system of the eye under examination, unless care is taken by means of fixed apparatus to minimise spherical aberration and oblique incidence of the light, that lens has a predominating influence upon the character of the image, and the estimation of the independent condition of the eye is rendered difficult. In the old treatises on optics we meet with the statement, important in practice, that with a convex lens of short focal distance, the inverted images of all objects farther removed from the lens than ten times its principal focal distance lie nearly in one and the same, that is, the posterior principal focal plane. Hence in the method of the inverted image the unavoidable error would at the least amount to from 1-20th to 1-40th of an inch. In reality, it is even greater, owing first, to the impossibility of securing and maintaining the best position of the object lens ; and second, to the optic imperfection of the lenses commonly employed, which are mostly left too thick, so that spherical aberration is not sufficiently guarded against.

Professor Schmidt-Rimpler uses for the inverted image the shadow from a crossed grate of metal in front of the flame, as Coccius (Stimmel) does for the erect image. Whilst the flame placed laterally with the grate before it, as well as the eye under examination with a four inches convex lens, held about four inches in

front of it, remain fixed, the head of the observer, with the concave mirror before it, moves gradually backwards. A conveniently attached tape-measure with a ratch serves to measure the greatest distance (a) between the mirror and convex glass, at which the grate's shadow appears distinct upon the retina's image between the papilla and fovea. While the flame and the grate continue unmoved, the distance (b) is measured from the mirror to the place of the grate's image formed by the concave mirror alone. The distance $d = a - b$ denotes the refraction of the examined eye, since d in emmetropia is equal to f (that is, the focal distance of the convex glass); and it is less than f in myopia and greater than f in hypermetropia.

Having first worked with the original apparatus as described, Hirschberg then employed a narrower grate, and simplified the method by omitting the second measurement. "Being myopic, I have my far point at a fixed distance; any one not myopic may render himself so by means of a proper convex glass placed behind the sight-hole of his mirror. Henceforth a only need be measured and the fixed distance deducted from it, in order to determine d. Upwards of a hundred careful observations, with a comparative trial in each case of the erect image, have proved that whilst Schmidt's plan can always be easily and expeditiously accom-

plished, the latter is yet the more accurate of the two, and affords the additional advantage of a considerably magnified image of the most important region of the fundus. And again, the grate's image formed by the concave mirror held obliquely is astigmatic, *i. e.*, the horizontal and vertical shadow lines are not at the same time and distance seen with equal distinctness; so that really in every case a mean ought to be struck between two observations. It is self evident that, under such circumstances, the determination of an existing astigmatism cannot be an easy matter. The less oblique the incidence of the light upon the mirror, the better are the results, as we have seen before. Finally we must remember that on account of the strong light of the reflector, it becomes rather difficult for the patient to relax his accommodation."

To such a degree, in the comparison of the direct with the indirect method of examination, the former can certainly hold its own. And now it remains in conclusion, to consider the direct method in regard to its absolute value.

Mathematically, the method of the erect image is not exact itself, since a loupe, whether a compound convex lens or having, like that of Brucke, a concave ocular, is not, in reality, an adequate means for *meas-*

*uring distance.** If with a loupe we obtain a distinct image of an object A, we are not able from the known focal distance *f* of the loupe to calculate the unknown distance *a* of the object from the loupe, because we do not know to what degree the accommodation of our eye had been relaxed. Hence, neither the older nor the more recent attempts, particularly by military surgeons, to utilize the loupe (after the example of Burow), for the subjective estimation of the refraction have been able to secure the approval of ophthalmologists. Yet it certainly makes a great difference whether the eye, looking through the loupe, is that of a recruit or a random patient, or whether it is that of a *medical observer*; for the latter is certainly able, in a short time (say within a few hours, or days, or weeks), to *learn* how to see through a loupe; in other words, to use the Ophthalmoscope without any appreciable exertion of the accommodation.

While this latter statement has by some observers been doubted, their isolated experience should not be allowed to weigh against the testimony of others who find that in the repeated examination of the same eye they have invariably to resort to the same glass for correction of the ametropia. A good revolving Ophthalmoscope facilitates the examination materially. While

*It is different with an astronomical telescope.

doubtless this power of relaxation of the accommodation so essential varies in different individuals, I believe a great cause of dissent to be the imperfect state of most of the instruments still in use at the present time, combined with the lack of application and thorough working out of details so essential to the mastery of all nice points.

There is further always this little drawback attaching to the direct method, that we do not adjust for the *fovea centralis* of the patient's eye, because it is optically too little marked, and also because its being made the point of fixation involves an undue contraction of the pupil. In the method of Coccius (Stimmel) this fault is pretty well guarded against. A convex lens covered with a metal grate is in front of the flame; the incident pencils of luminous rays are rendered parallel, and are by a small plane mirror reflected into the eye to be examined, which, in its turn, is corrected for parallel rays by a glass held as straight as possible in front of it. The general practice however, is to put up with the flame of an ordinary lamp, and to accomodate for the lateral edge of the papilla, or for one of the fine blood-vessels coursing from the optic disc towards the *macula lutea*, the bright central lines of which are very readily perceived, or for the ring of connective tissue at the lateral edge of the papilla, or the granular aspect of the

fundus (the retinal epithelium,) thereabouts. Now the lateral edge of the papilla is about 3mm., or 12 angular degrees distant from the *fovea centralis*, and still it is the refraction of the latter (i. e., its relative position to the principal focal point of the quiescent dioptric system of the eye) which we are seeking to determine. Experience shows that in cases of emmetropia and hypermetropia the error is but very slight, as is confirmed by the controlling trial of glasses for the correction of the atropinized eye (Mauthner, Schnabel, etc.,) where as in myopia, even of moderate degree, the difference is sometimes found to amount to 1-36th of an inch. In cases of ametropia, however, which call for 10 D or 12 D or upwards, as *e. g.*, in aphakia, the error (0.5 D to 1 D) is utterly insignificant. It is not the absolute, but the relative amount of the latter which requires to be weighed; nor must we lose sight of the fact that, in many disquisitions on physiological optics, the best authors, physicists as well as physiologists, look upon errors, amounting to from 5 to 10 per cent. of the quantity sought, as matters of course. It has no sense, at the present time in our examination of patients, to aim at any greater accuracy. If approximately correcting glasses are supplied in a case of hypermetropia of 12 D, a slight forward or backward movement imparted to the spectacle-frame suffices to alter the strength of

the glass by more than 1 D. It is, therefore, quite unnecessary, so far as the stronger glasses of the refraction Ophthalmoscope are concerned, to retain the interval of 0.5 D. Beyond 10 D or 12 D, it is better for the rapid and sure determination of the proper glass to have the interval equal to 2 D.

In the method here advocated we estimate, it is true, the refraction of the eye for red light, and not for that of the greatest brightness, with which, however, ordinary vision is concerned. Badal makes the difference to be equal to 0.75 D, but a simple calculation shows it to be no more than 0.25 D, and hence entirely insignificant.

In adjusting for the fine median blood-vessels, we determine in reality the refraction of the vascular instead of that of the sentient layer of the retina, the distance between the two being a small fraction of 1 m. The thickness of the retina between the papilla and fovea is about 0.3 mm. Hence the possible error is certainly less than 0.15 mm., that is under plus 0.5 D, seeing that in the schematic emmetropic eye a distance in depth 0.3 mm., corresponds to a difference of refraction equal to 1 D.

All these trifling errors interest us only in connection with the question whether such slight deviations from the emmetropic condition are capable of being diagnosed.

In cases of pronounced ametropia, they may be left out of account entirely. The conclusion is, then, that in the direct method, pure and simple, we have a secure means of establishing the presence even of an ametropia of 1-48th of an inch, that is one corresponding to one of the weak glasses of the ordinary trial cases, (the weakest in some foreign ones.)

This quite accords with the experience of many that the objective method of determining the refraction for the most part yields more exact results than the subjective, in which we depend solely on the statement of the patient.* The former frequently discloses small differences between the two eyes, of which the patient had not become aware in the selection of glasses.

Among other advantages of the objective method, it is far more expeditious than the subjective method. It is also of much more extended scope, being equally applicable in the cases of children and illiterate persons, of simulation and amblyopia; and, finally it enables the analysis of astigmatism, qualitative as well as quantitative, to be made in the most reliable manner. Yet, for all that, we cannot dispense with the trial-case. It is always advisable, wherever it can be done, to confirm by the subjective method.

*See note at the foot of page 50.

CHAPTER VIII.]

EXAMINATION OF THE HEALTHY EYE.

It is assumed that the reader, who undertakes to employ the aid of the Ophthalmoscope, has first from books at least, gained a fair knowledge of the anatomical structures of the eye, together with their names and relations. It will therefore not be deemed necessary in the succeding pages to explain the terms employed.

As in every other branch of physical diagnosis, a familiarity with the appearances in health is necessary to the detection of disease, so it is with the eye; the condition of the parts in health must be the standard by which to estimate the nature and extent of disease. Let the student first apply himself to the study of the normal structures, and learn to recognize them in all their variations, and he may then, and not until then, proceed intelligently to the complete mastery of the subject.

Color of the Fundus.—As already mentioned, the reflection from the fundus is reddish, but its tint varies greatly in different individuals. "Among dark races the fundus of the eye is of a brownish gray color, while

among the European races it is more of a crimson orange." The variations of color and tint depend upon the amount and color of the pigment filling the cells of the choroid and obscuring to a greater or lesser degree the choroidal vessels.

In people of very light complexion, the fundus is often found to be of a bright scarlet color. Such is the case in the Swede, while in the Italian or the Spaniard, the color is proportionately darker.

Examination of the fundus can hardly be regarded as complete without the employment of both the direct and the indirect methods of exploration. The first shows only a very limited portion at a time, but this portion is highly magnified and in its true color. The second shows a large field at a time, and enables the observer to note the relation of the parts more accurately; but the color of the image is not a true representation of the color of the object, nor is the image so highly magnified as by the direct method.

The Optic Disc.—The disc or papilla, is the point where the optic nerve terminates or expands into the retina. It is usually round, or slightly oval with its long diameter vertical. Its color varies, and the darker the eye, the whiter the disc appears by contrast with the surrounding choroid. The color is generally pink

or rosy, and varies from this to a steel gray. In very dark eyes the disc appears white.

The color is derived from three sources,—the white of the connective tissue, the red of the capillaries and the bluish-gray of the nerve tubules. The circumference of the disc is well defined; it is enclosed first, by the white ring of the sclerotic, and second, by the darker choroidal border.

The sclerotic ring which encloses the nerve appears as a slender zone of white, usually most marked at the outer side of the disc. Sometimes only a portion of this ring can be seen, or it may even be entirely obscured. Outside of the sclerotic ring, the border of the choroid is plainly seen. Its general color is brownish-gray, but the outer border is often of a darker hue, owing to a crescentic shaped deposit of pigment in this situation.

The central surface of the disc is depressed below the general level, and of a whitish appearance. It frequently has a stippled look caused by the holes through which the bundles of nerve fibers pass. It is at this point that the *arteria centralis retinæ* and the accompanying vein pierce the optic nerve. This depression is called the *porus opticus*, and its white appearance is due to the connective tissue enclosing the vessels.

Although the central artery of the retina usually pierces the disc at its center and bifurcates as soon as it emerges, one branch passing upwards and the other downwards, such is not always the case. The artery may appear at other points of the disc, and has been observed to emerge as several branches. After bifurcating, the branches continue to divide dichotomously, continuing in all directions towards the periphery of the retina. The veins enter the disc at a little distance apart, and correspond to the arterial branches, though the former are sometimes double. The veins are tortuous in their course and larger than the arteries. Sometimes a spontaneous pulsation may be noticed in the central veins, and this may be augmented by gentle pressure upon the eyeball. The veins are of a darker and of a more uniform color than the arteries, and they usually pass under the latter. The apparent calibre of the vessels will be found to differ with the magnifying power used. The arteries, in contrast with the veins, are straighter, of a brighter red, smaller, and the pulsation cannot be seen. They usually cross over the veins, and along the center of

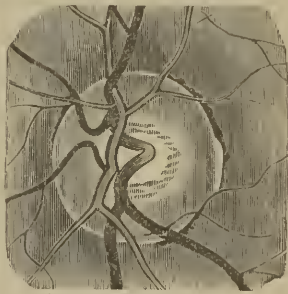


FIG. 21.

each may be noticed a bright whitish line. This whitish line is scarcely observable on the veins.

Figure 21 is copied from a drawing by Jaeger, and represents the healthy appearance of the disc as seen in the erect image. The dark vessels are the veins, the light ones, the arteries.

The whole is much enlarged.

Color of the Disc.—This is not uniform, the inner half being of a pinkish tint, and the outer half presenting more of a gray or mottled appearance. The inner portion is more of a pink than the outer, owing to its being more thickly covered with nerve fibers and vessels. The central depression, its whitish appearance, the outer grayish mottled hue, and the more decided pink of the inner half, are all subject to considerable variation, but are characteristic marks in most healthy eyes.

The Retina.—The retina is so nearly a transparent structure that it reflects very little light and is therefore generally invisible. In very dark persons it may sometimes be seen lying over the choroid as a grayish layer. Its appearance may well be likened to the bloom on a peach.

The *macula lutea*, or yellow spot, is not easily recognized. but it is situated on the axis of vision about one or two lines outward from the disc. No retinal ves-

sels cross this spot; they pass either above or below. This fact helps to determine its position more readily. The color generally seems to be a bright red, and in the center is a bright spot known as the *fovea centralis*, or central pit.

The Choroid.—The anatomy of the choroid shows it to be a vascular and pigmentary structure. An elastic lamina lies innermost, and close behind this, separated from it only by the hexagonal cells, lies a dense capillary network. The larger choroidal vessels lie next to the sclerotic, and among them are distributed the most of the pigment cells. In persons of dark complexion, the hexagonal cells conceal the choroid from view; but in persons of a lighter hue, these cells contain no pigment and allow light to pass to the vascular structures. This explains the scarlet appearance of the fundus in the latter, and the brownish-gray appearance in the former.

As a method of acquiring dexterity in using the Ophthalmoscope, it has been recommended that beginners undertake to make sketches of the disc, and a portion of the surrounding fundus in some person's eye. The frequent repetition of laying down and re-adjusting the instrument, soon gives that ease and celerity to the operation which is so desirable.

CHAPTER IX.

OPHTHALMOSCOPIC APPEARANCES IN DISEASE AND MALFORMATIONS.

Opacities.—These occur in the cornea, lens and vitreous, and are therefore situated at different depths. As far back as the posterior lens capsule, as has already been noted, opacities may be seen in their true colors by lateral illumination, and even very minute ones may be detected; but with the mirror alone it should first be ascertained whether the media are clear. Once assured that an opacity exists, its depth should be determined, and then, if it is within range, the lateral illumination may be used. With the Ophthalmoscope, opacities appear as dark spots of irregular size and shape on a red background. With the lateral illumination, they generally appear as gray or light spots upon a dark background. With a very brilliant illumination, very small opacities may be invisible; it is therefore best to employ a very weak light at first.

In examining for opacities with the mirror, in order to prevent the image of the fundus from obscuring or confusing them, the mirror should be held at such a

distance as will prevent the observer from getting any image of the fundus. In order to do this, a lens of about eight inches focal length may be used behind the mirror and the latter be held at a distance of seven or eight inches from the eye under observation.

To determine the depth of an opacity, it may be remembered that all opacities in front of the posterior lens capsule are readily located by means of the oblique illumination. The turning point of the eye, or the point which remains stationary while the eye is in motion, is situated either at, or a little behind, the posterior pole of the lens. Now, if the eye is moved in various directions, opacities in front of this turning point, or pivot, will move in the same direction as the cornea; and it is likewise obvious that opacities behind this point will move in the opposite direction. An opacity situated at the turning point would scarcely move at all. The reflection of the mirror upon the cornea does not move with the movements of the eye. This corneal reflection should therefore be taken as the fixed point by which to measure the extent of movement of an opacity; and the extent and relative direction will show the approximate depth.

Opacities of the Cornea.—These are best seen by the oblique method. The unaided eye will detect those of appreciable size. With the former method, the loca-

tion, size and color can be easily and fully determined.

Opacities of the Lens.—Sometimes spots are seen upon the anterior capsule, the posterior capsule and the lens being unaffected. Usually these are deposits of lymph or pigment resulting from iritic or corneal inflammation.

Strictly speaking, the term cataract should be limited to an opacity of the lens, though the term is applied to opacities of the lens capsule as well. There are therefore two general classes of cataract, the capsular and the lenticular.

It is not my purpose to speak of cataract farther than pertains to the Ophthalmoscopic appearances of the different varieties. These will be better understood if a few leading characteristics are added.

Capsular cataract is an opacity of the lens capsule, which generally encroaches on the area of the pupil. It has a whitish appearance and seldom occurs without the lens itself having been previously involved.

The anterior capsule is more frequently affected than the posterior. The trouble is not so much in the capsule itself as on its inner surface, where, with the oblique illumination, crystals of cholesterine or chalky concretions may be seen.

Lenticular cataract may be divided into four varieties: the soft, the cortical, the hard and the zonular.

Soft Cataract.—This occurs among infants and young children and is often congenital. Dilate the pupil with Atropine; the lens shows a bluish-white opacity which is usually uniform and free from striæ. With the Ophthalmoscope the opacity will be found to reach from the center of the lens to its circumference and no portion of the fundus will be visible. Occasionally, opaque whitish spots are noticed beneath the capsule.

Under the head of soft cataract, traumatic cataract may be mentioned as sometimes analogous in appearance. If an injury to the lens is extensive the aqueous humor pervades its whole substance and renders it opaque. In slight injuries only a small and irregular portion of the cortical substance is involved. The history of the case almost precludes the possibility of a mistake in diagnosis.

Cortical Cataract.—Before fully formed, the cortical cataract appears as a series of striæ running from the circumference of the lens towards its centre. These striæ are often situated in the posterior substance of the lens, but as the cataract advances, they become white, increase in breadth and finally occupy the whole lens. Dilate the pupil with Atropine, and the opacity will appear quite uniform but marked with pearl-like bands, and perhaps of a yellowish tint at the centre. But with the Ophthalmoscope, it will be

noticed that the margin of the lens allows a few rays of light to pass from the fundus, the red reflection being seen. The central portion of the lens appears opaque and dense, surrounded by a dim reflection from the fundus. In the soft cataract, no striæ or colored reflection are seen.*

Hard Cataract.—Senile or hard cataract seldom affects a person under forty years of age. It first appears as an amber-colored opacity, most marked at the nucleus, the cortical substance remaining comparatively unaffected. The amber-colored center is the characteristic feature throughout the course of its formation. In the earlier stages, if the pupil is dilated with Atropine, small opalescent striæ may be seen extending inwards from the circumference, and as the cataract advances, these become more apparent. The Ophthalmoscope shows the circumference more transparent than the center even in the latter stages. Spots of fatty epithelium are often observed beneath the inner surface of the capsule.†

*"In some cortical cataracts we find only an immense number of very small dots or short streaks (dotted cortical cataract). Occasionally a single, large, wedged shaped opacity will form at some part of the cortex and remain stationary and solitary for many years. Sometimes, though no opaque striæ are visible by focal illumination, one or more dark streaks are seen with the mirror, which alter as it is differently inclined. These "flaws" in the lens are comparable in their optical effects to cracks in glass, and must always be looked on as the beginning of cataract." (Nettleship.)

†"A few cataracts beginning at the nucleus, and many beginning at the cortex, are not senile in the sense of accompanying old age, and are, there-

Zonular Cataract.—This opacity is usually congenital, and most often occupies layers of the posterior cortical substance of the lens, and is most dense at the axis. Dilate the pupil with Atropine, and unless the case is far advanced, the Ophthalmoscope clearly reveals a portion of the fundus through the circumference of the lens. Even a dim reflection of the fundus may be seen through the denser portions. The opacity appears, by oblique illumination, as a whitish-gray film apparently upon the posterior lens capsule. Sometimes striæ radiate from the central portion, but the circumference of the lens is often completely transparent. This form of cataract may be progressive or may remain stationary for many years.

Dislocation of the Lens.—The lens may be either partially or completely displaced, and in almost any direction. In partial dislocation, if the pupil is well dilated with Atropine, the change in the position of the lens may be noted either by oblique illumination or by the Ophthalmoscope. Using the Ophthalmoscope by the direct method, the edge of the lens may be seen

fore, not hard. Some such are caused by diabetes, but in many it is impossible to say, excepting by a general reference to bad health or premature senility, why the lens should have become diseased. Many such are known as "soft" cataracts when complete. They generally form quickly in a few months. A few are congenital. Whether nuclear or cortical, they are whiter and more uniform looking than the slower cataracts of old age, and the cortex often shows a linear glisten like satin, or flaky appearance like crystalized spermaceti." (Nettleship.)

as a distinct, dark, curved line lying over the background of the fundus. Not only this, but if the lens is so far dislocated laterally, as to leave a portion of the pupil unoccupied, a distinct erect image of the fundus can be seen through that portion of the pupil, and the part of the fundus thus seen will be very hypermetropic.

Complete dislocation of the lens into the anterior chamber can scarcely be mistaken even when the lens is quite transparent. If the dislocation is backwards into the vitreous, with the Ophthalmoscope its location can be readily ascertained. It will appear nearly natural in outline, darker in color, occupying the lower portion of the vitreous while the head is erect. Using the oblique illumination, no reflection from the anterior capsule is apparent. When the lens lies partially across the pupil, it acts as a prism and a double image of the fundus may appear, but when it is entirely without the axis of vision, the eye becomes intensely hypermetropic and the details of the fundus appear very small.

Changes in the Vitreous Humor. Opacities.—In inflammation of the vitreous humor it is diffusely clouded with a grayish mist, which partially or completely obscures the fundus.

Besides diffuse opacity, there often exist opaque bodies varying much in shape and size. If the vitreous

is in a fluid condition, these move about with the motions of the eye, and can readily be detected with the Ophthalmoscope. Opacities from hæmorrhage appear bright red, unless very extensive, when they may cause the whole fundus to appear dark. The location and amount of hemorrhage is subject to no rule. After absorption has begun, the color and form of the blood spots change to various irregular, fibrinous or filamentous shreds, either fixed or floating.

Synchisis, or Softening of the Vitreous.—In a softened, fluid condition of the vitreous, a large number of small bodies are to be seen suspended in its substance; in fact, unless these bodies are present it cannot be said positively that a fluid condition of the humor exists. They are often in the form of fibrinous threads, interspersed with crystals of cholesterine.

An abundance of cholesterine crystals generally is present when the vitreous is in a fluid state, presenting a beautiful appearance. While the eye is at rest these crystals subside more or less completely toward the bottom of the chamber, but with every movement of the eye they become diffused through the fluid, and appear like particles of sparkling gold-dust. The term sparkling synchisis is applied to such a condition.

Foreign Bodies.—When a foreign body has entered the vitreous, if the media remain clear, the use of the

Ophthalmoscope will reveal its character and position. After some days have elapsed, the body is likely to become gradually covered with the products of inflammatory exudation, concealing it from view.

CHAPTER X.

REFRACTIVE DISORDERS.

There are several ways of determining the refraction of an eye. It may be found by means of the incident light; by means of the lens necessary to use in order to see the upright image; by means of the enlargement of this image; by the distance at which the inverted image is formed; and by the enlargement of this image.

The way most used, however, because the simplest and easiest, is that of finding the lens required by the examiner, (any ametropia of his being first corrected, and the accommodation of both examiner and patient being fully relaxed,) to clearly and distinctly see the fundus of the eye under examination.

Myopia.—It will be remembered that in myopia, the rays converge to a focus before reaching the retina. In other words the principal focus of the dioptric media lies in front of the retina.

Hence rays issuing from the retina of a myopic eye do not emerge from the cornea parallel, as is the case in emmetropia; but coming from a point beyond the principal focus, they emerge as convergent rays. They cannot as convergent rays be brought to a focus upon

the observer's retina, but after they cross each other and become divergent, the observer can obtain a distinct image. The image is an inverted one, as is proven by the fact that it moves in the opposite direction from the observer's head. The head of the observer must be from twelve to sixteen inches from the eye under examination.

An erect image may be seen at a short distance by interposing a concave lens behind the mirror; but the lens should be of sufficient power to render the convergent rays parallel. The focal length of this lens will approximately represent the degree of the myopia existing in the eye under observation, and therefore the number of the lens necessary to correct it.

Hypermetropia.—Parallel or divergent rays of light entering the hypermetropic eye converge to a focus situated behind the retina. The principal focus of the dioptric media is therefore behind the retina. Rays from the retina are therefore from points within the principal focus, and in consequence emerge divergent. At a distance (sixteen to twenty inches) these rays can be brought to a focus upon the observer's retina, and form a distinct erect image. That the image is erect is proven by its moving in the same direction as the observer's head.

Rays issuing from a hypermetropic eye may be ren-

dered parallel by a suitable convex lens. The focal length of the lens which will render the divergent rays parallel, enabling the observer to see a clear erect image of the eye at a short distance, (two or three inches), will give approximately the degree of existing hypermetropia.

The size of the inverted image is directly proportionate to the focal distance of the convex lens used; and other things being equal, that of the myopic eye is smaller, and that of the hypermetropic eye larger, than that of the emmetropic eye.

"The inverted image produced by a convex lens of plus $\frac{1}{2}$ an inch, (20 D) placed at a little less than two inches in front of the cornea is, for the emmetrope, 3.6 times greater than the object; smaller for the myope, and larger for the hypermetrope, the difference increasing with the increase of the ametropia.

"The relation of the size of the inverted image of an ametrope to that of the upright image under the conditions mentioned, is as follows: for emmetropia, 1:5.5; for hypermetropia of 7.9 D, 1:4.7; for myopia of the same degree, 1:7.1."

But in estimating the degree of either hypermetropia or myopia by these methods, one source of error must be carefully guarded. It arises from the fact that comparatively few ob ervers can, in looking at near

objects, prevent the involuntary action of the ciliary muscle. To make the results of value, both the observer's and the patient's accommodation must be relaxed during the examination. Repeated practice must be had until the examiner can accomplish this relaxation, or an allowance must be made for that which cannot be overcome.

To practice for this relaxation of the accommodation, emmetropes and hypermetropes may look through a convex lens at objects situated at the focus of the lens; and practice bringing their eyes to a parallel condition by placing before one eye a prism with its base inward. It may also be found advantageous to examine the inverted image through a moderately strong convex lens, (plus 3 D.)

Astigmatism, and Conical Cornea.—In most eyes the refraction varies slightly in the different meridians of the cornea. Usually rays entering the eye in the vertical meridian are focussed somewhat nearer the cornea than the rays in the horizontal meridian. The variation is usually so slight as to be unnoticed; but where the want of symmetry in the corneal curvature is great, confused and indistinct images are formed upon the retina and the condition is called astigmatism. Sometimes the crystalline lens presents irregular curvature also.

Astigmatism is either regular or irregular; and of regular astigmatism there are three varieties, the simple, the compound, and the mixed.

When one principal meridian of the cornea is emmetropic and the other myopic or hypermetropic, astigmatism is said to be simple. If the meridian of abnormal curvature is myopic the astigmatism is simple myopic; but if this meridian is hypermetropic, the astigmatism is simple hypermetropic.

When different degrees of either myopia or hypermetropia exist in both principal meridians, the astigmatism is called compound. If both principal meridians are myopic, it is compound myopic. If both principal meridians are hypermetropic, it is compound hypermetropic.

When one principal meridian is myopic and the other hypermetropic, the astigmatism is said to be mixed.

Irregular astigmatism is caused by differences of refraction in one and the same meridian.

The Ophthalmoscope is a most useful means of diagnosis in these disorders of refraction. By the direct method, in regular astigmatism, the optic disc appears oval, and the elongation is in the direction of greatest curvature. By the indirect method the reverse is true. Sometimes in normal eyes the disc is oval; hence it will never be safe to make a diagnosis from the apparent

form of the disc by only this method of examination. If the disc appears oval in one direction while viewing the upright image, if astigmatism is present, it should appear oval in a direction at right angles to the first when viewing the inverted image.

The presence of astigmatism may also be determined by observing the relative distinctness with which vessels running in different directions are seen. For example, vessels running vertically may appear clearly focussed, while those running horizontally are indistinct and confused.

Suppose the observer's eye is at a minimum distance and adjusted for parallel rays, but upon exerting his accommodation the first set of vessels becomes dim and the second set clear; he is manifestly dealing with a case of simple hypermetropic astigmatism. But if, under the same conditions, he cannot by any accommodative effort obtain a distinct image of the second set of vessels, the case is one of simple myopic astigmatism. In a case of compound hypermetropic astigmatism, if the observer's eye is at a minimum distance and adjusted for parallel rays, he can only see the vessels or other details by exerting his accommodative power; and different degrees of accommodation will be required for successively focussing vessels running in the direction of different meridians.

Astigmatism may also be detected by the indirect method; for if the lens is held at its principal length from the eye and then gradually moved nearer, the disc appears more and more elongated in one diameter; but if instead, the lens is gradually withdrawn, the disc appears elongated in the diameter at right angles to the first.

Thinning and increased curvature of the cornea sometimes occurs while its substance remains transparent. This condition is known as conical cornea. A cone-shaped prominence involves a part or the whole of the cornea. Its summit is always blunt and its sides vary much in height and abruptness. This can usually be seen with the unaided eye. When simple inspection or the oblique illumination fails to detect an elevation of this kind, the Ophthalmoscope may be employed. Using only the mirror and reflecting the light upon the eye from different angles, the side of the cone opposite the light will appear shaded or darkened. But such a test will not be needed except in slight degrees of the affection.

By the indirect method of examination, if the lens is moved from side to side, portions of the image of the fundus will appear much distorted and rapidly change shape with the movements of the lens.

TABLE

SHOWING THE DIFFERENTIAL DIAGNOSIS OF THE REFRACTION OF THE EYE.

	In an eye that is		
	HYPERMETROPIC, (Symbol H.)	EMMETROPIC, (Symbol E.)	MYOPIC, (Symbol M.)
The optic axis	Is shorter than that of the normal eye.	Is normal.	Is longer than that of the normal eye.
Far vision is improved	By convex glasses.	By no glasses.	By concave glasses.

APPEARANCES WHEN VIEWED WITH THE OPHTHALMOSCOPE—DIRECT METHOD.

The image of fundus at some distance from the eye, is	Smaller than normal.	Normal.	Larger than normal.
The image moves with the observer's head	In the same direction.		In a contrary direction.
The position of the image seen is	Behind the eye.		In front of the eye.
Close to the eye, the image of the fundus can be seen	With a convex lens, or without a lens, or with a concave lens.	Without a lens, or with a concave lens.	With a concave lens only.

APPEARANCES WHEN VIEWED WITH THE OPHTHALMOSCOPE—INDIRECT METHOD.

If the lens is moved farther from the patient's eye, the image	Becomes smaller.	Does not change.	Becomes larger.
The size of the image	Is larger than normal.	Is normal.	Is smaller than normal.
The image is best seen at a distance of	About 30 inches.	About 20 inches.	About 12 inches.

CHAPTER XI.

THE FUNDUS OF THE EYE.

The consideration of some of the changes of the fundus of the eye in disease will occupy the closing pages. The plan of this treatise does not permit of introducing, to any extent, the etiology or attendant symptoms of any of the special diseases of the eye. My purpose will be accomplished if the rudiments of Ophthalmoscopy are made plain and the study of diseased appearances intelligently begun. The changes which can be readily observed will be described; the chief Ophthalmoscopic appearances of the optic disc, the retina and the choroid in disease will be separately reviewed, and some practical hints regarding the nature of the changes and how to look for them will be added. Their thorough elucidation should then be sought out in some of the larger works devoted to the eye.

It may be well to remind the student that, owing to the intimate relations of the structures at the fundus of the eye, he must not expect to often find marked alterations in one part without more or less important changes in parts adjacent. In most cases where symptoms of disease exist which, directly or indirectly, may

be referred to the fundus, it is well to explore this portion of the eye in all directions taking the optic disc as the starting point. Very serious disorders may have their origin in the periphery as well as in the center or in other portions of the fundus, and the situation of any abnormal appearance should be carefully determined.

The location of any spot may be determined by noting its distance from the optic disc and at the same time considering the direction from which we look into the patient's eye.

Elevations and depressions of the surface at any point must not only be recognized but must be distinguished from each other. With the binocular Ophthalmoscope alterations in surface level appear in their true characters, but the case is different with the monocular instrument. With the latter, attention must be directed to the course and appearance of the vessels; for as these ascend or descend from one level to another they describe a more or less acute curve. A slight alteration in surface level will cause a very slightly perceptible curve; but on the other hand, the curve may be so abrupt and extensive as to hide portions of the vessels from view.

If the details of a portion of the fundus are clearly focussed while those of closely adjacent portions are

indistinct, we may suspect a relative difference in surface level unless the appearance can be accounted for by slight opacities, astigmatism or otherwise.

To ascertain whether a part is elevated or depressed, apply the tests for hypermetropia and myopia respectively. An elevated portion of the fundus will lie within the principal focus of the dioptric media and therefore be hypermetropic. The floor of a depression lies beyond the principal focus of the dioptric media and is myopic. By the direct method an image of each condition can be seen at a distance, the first erect and the second inverted. An elevation or a depression in the *fundus oculi* can be measured by mathematical calculations based upon accurate estimates of the states of refraction of the summit and base of an elevation, and the margin and bottom of a depression.

Those desiring, in a work of this kind, to learn something of the nature of these calculations, will find in the last chapter a description of those most useful and simplest.

The Optic Disc.—The optic disc, or papilla, is frequently the seat of pathological changes, and its appearance differs much in the various affections. To know what is normal is to know what is abnormal, but the latter by no means implies a knowledge of the true significance of each change observed. The changes

which oftenest occur together, make up well established conditions, or those which have received definite names; and the following conditions of the disc will be reviewed and their distinguishing appearances described: viz. hyperæmia, inflammation, anæmia, atrophy, excavations and pigmentation.

Hyperœmia.—This accompanies hyperæmia of the optic nerve, and if confined to one eye, an advantage may be gained by comparison with the healthy eye (a fact not to be forgotten in other disorders).

The disc becomes much reddened, its vessels are fuller and its margins not clearly defined owing to a haziness which extends over into the retina. The vessels of the retina are generally more or less enlarged, and often the whole fundus, including the disc, is of a uniform red or scarlet hue. In the latter case, the position of the center of the disc can be determined only by the position of the central vessels.

Inflammation.—In optic neuritis, or inflammation of the nerve, the phenomena in the disc differ with the origin of the disease and its successive stages; but in the earlier stages the following symptoms generally present themselves: The disc appears larger than in health and is red, swollen and somewhat œdematous. Its surface is convex instead of concave, its margin hazy and dimly defined. The appearance of the surface and

margin of the disc is often described as "wooly", and is due to hypertrophy of its connective tissue. The vessels from the retina cannot be traced beyond its margin, and their exit from the eye is frequently lost to view. New vessels often become developed upon the surface of the papilla, and not unfrequently its surface and vicinity are the seat of numerous blood extravasations; both of which causes render it very red and vascular. The disc is prominently elevated and can be seen at some distance from the eye in the erect image.

Owing to the firm and unyielding nature of the scleral ring which encloses the nerve's extremity, the swollen and infiltrated nerve presses upon its own vessels and obstructs the circulation. As a result the retinal veins are more or less engorged, dark and tortuous, while the arteries are much contracted and at times scarcely distinguishable.

Severe cases of optic neuritis are usually followed by more or less complete atrophy of the papilla and nerve, and this constitutes the later stages. (See Atrophy).

Anæmia.—In anæmia both eyes are equally affected, each disc being unnaturally white. The retina and choroid are also wanting in color. The eyes do not light up well. The general state of health in which the patient is found helps to explain the anæmic state of his eyes.

The paleness of anæmia of the disc may be distinguished from the paleness of atrophy by observing the following facts. In anæmia the fundus also is pale, but in atrophy it remains red because the choroidal vessels are normal in color. The paleness of the anæmic disc is not so striking as that of the atrophic, owing to its lack of contrast with the surrounding fundus. In all stages of anæmia, although the amount of blood is small in both the central arteries and veins, these vessels can be distinguished from each other. In the earlier weeks of atrophy the central veins are dilated and the arteries small; but later, both sets of vessels are reduced in size and number and finally become undistinguishable from each other. It not unfrequently happens that no vessels can be traced over the white expanse of an atrophied disc. Perhaps a single artery or vein may remain, though it is generally destitute of branches.

Atrophy.—Two classes of atrophy of the optic papilla are usually described, viz., the primary or progressive, and the consecutive. The appearances of the disc in atrophy may be enumerated as unnatural whiteness, decrease in calibre of the retinal vessels (the veins diminishing in size somewhat later than the arteries) and a peculiar excavation of the disc itself. The character of this excavation is further described

and illustrated under Excavations, which see. Sometimes the whiteness is very great, and in other cases the color is bluish-white. The small nutrient vessels upon the surface have generally disappeared, and this aids in producing its unnatural whiteness. The latter is especially marked in cases of primary atrophy in which the outlines of the disc though sometimes irregular, are clearly defined.

Atrophy consecutive upon optic neuritis is usually for a long time distinguishable from other kinds. The papilla remains swollen, and its outline indistinct. Its color is of rather a dull grayish-white; but after a time distinctions become lost, and it assumes the same appearance as the other varieties. In most cases of atrophy of the disc both eyes are affected, but not always to an equal extent.

Cupping or Excavation.—This occurs in three varieties, known respectively as the physiological, the atrophic, and the glaucomatous cups.

The first, or physiological cup, has already been mentioned as a congenital excavation. It never involves the whole disc, is usually very small and shallow and generally confined to the central portion, though quite often displaced.

The walls are in most cases slightly inclined from the center to a higher level. Exceptionally they are

steep or irregular, or the cup may be funnel-shaped. As the retinal vessels enter the disc, the curve more or less acutely as they pass the margins of the cup. The whole fundus moreover looks healthy and cheerful, and there are none of the symptoms accompanying the other diseases.

Fig. 22 shows a sectional view of the nerve and disc, giving the form of the physiological excavation.

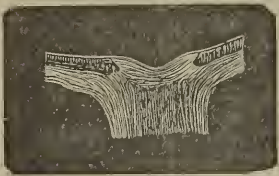


FIG. 22.

In the atrophic cup there is loss of nerve fibers, blood vessels, and sometimes connective tissue. The blood vessels are not usually all lost, but those which remain are altered in size and appearance as before described. The excavation is shallow, but involves the whole surface of the disc. It is also deepest at the center. In the beginning of atrophy the whiteness is very bright, and occupies a portion of the disc near its center. Later, this whiteness extends and occupies the whole surface of the disc quite up to the sclerotic ring, and the latter stands out very distinctly. The ultimate color of the disc is apt to be bluish or grayish white. The shallowness of the excavation and its gradual inclination from center to edge cause no very marked curve or displacement of those vessels which remain. They pass over its edge with

little or no appreciable curve, and no part of them is lost to view.

Fig. 23 is a sectional view of the atrophied disc, showing its peculiar excavation.

FIG. 23.

The glaucomatous cup is usually very deep, and occupies the whole surface of the disc. In its early stages the walls may be steep, straight and only moderately deep, but as the disease progresses the cavity deepens and the edges of the disc overhang its sides. In the first case the continuity of the central vessels may be traced, though they necessarily describe a very sharp curve on passing the edge; but when the sides become excavated laterally, parts of these vessels are lost to view. Vessels from the retina upon reaching the margin seem to abruptly break off, but remnants of them may again be dimly seen near the center of the floor of the excavation.

A shadow surrounds the *porus opticus* in the form of a ring and changes with the movements of the Ophthalmoscope. This shadow is cast by the walls of the excavation and was formerly the cause of an optical illusion, and cupped discs were regarded as prominent ones. Deeply cupped discs have a mottled appearance, the result of atrophic changes and the manner in which

the light falls upon them; the usual color is gray or grayish-white; it may be greenish or even very white.

Another characteristic appearance in the glaucomatous cup is the so-called parallax of glaucoma. This is made apparent while using the indirect method of examination and slightly moving the objective from side to side. As the objective is moved, both the floor and the margin of the excavation move too, but the latter much more rapidly than the former; and it requires no great movement of the lens to cause the margin to move some distance across the bottom of the excavation. Arterial pulsation so often noticeable in glaucoma is another distinguishing point, but the characteristic displacement of the vessels, the abrupt sides of the cavity, and the other points already described, can hardly fail to show the nature of the glaucomatous cup. Partial cupping of the disc has been sometimes observed in glaucoma. It is recognized by the same marks as the other forms.

FIG. 24.

Fig. 24 is a sectional view giving the general shape of the glaucomatous excavation.

Pigmentation.—It is not unusual to find quite a deposit of pigment along the edge of the optic disc, but very rarely does pigment become deposited within the

limits of the disc itself. Cases have been reported, however, in which marked pigmentation of the disc occurred. This abnormal change has usually followed some severe accident to the eye, and is due to the escape of coloring matter from the blood.

CHAPTER XII.

THE FUNDUS OF THE EYE, CONTINUED.

The Retina.—Affections of the retina which have been described in ophthalmic literature are somewhat numerous. The following will be especially considered: anæmia, hyperæmia, inflammation, atrophy, detachment, tumors and embolism of the central artery.

Anæmia and hyperæmia of the retina have been considered under the same affections of the disc with which they are associated.

Inflammation of the Retina (Retinitis).—In most cases of retinitis the disc is inflamed also. In all cases of optic neuritis of any extent, the retina is involved. The concurrence of inflammation in both of these structures is known as neuro-retinitis. But affections of the retina are best described separately from those of the disc. The varities of retinitis will be examined separately from each other.

Acute Parenchymatous Retinitis.—This variety presents the following ophthalmoscopic appearances: The fundus of the eye is uniformly scarlet and the outlines of the optic disc lost. The central artery may remain normal but the veins are enlarged and unusually

tortuous. Blood extravasations of varying form and extent are usually scattered over the expanse of the retina. An effusion of serum or lymph renders the retina more or less swollen and œdematous. There is a hazy look about the fundus, in most cases, owing to the retinal infiltration.

If the disease assumes a more chronic form, the inflammatory exudation causes the disc, as well as the surrounding fundus, to look opaque, and the character of the exudation determines the color of the opacity. An opacity resulting from serous effusion is pale and ot a grayish or grayish-pink color. An exudation of lymph causes an opacity which is nearly white. If the exudation occupies the external retinal layers, the retinal vessels will not be obscured; if the internal retinal layers are involved the vessels will be hidden to an extent depending upon the nature and size of the exudation.

Hyalitis, or inflammation (with sequent haziness) of the vitreous body, is an accompaniment of acute retinitis, especially if the internal layers are affected; this may obscure to a considerable extent the real appearance of the retina. The spots of blood extravasation vary in color, size and appearance with the depth at which they are situated, the length of time they have existed, and whether they originated

from the arteries or from the veins. Farther space will be devoted to a description of these under *retinitis apoplectica*. Inflammatory exudations may occupy the whole or a part of the retina, and may be scattered about in spots or in clusters of spots.

Serous Retinitis.—Serous retinitis is not easily recognizable with the Ophthalmoscope. It is characterized by a delicate, uniform, bluish-gray or greenish opacity, which appears like a cloud over the surface of the retina. The infiltration of serum is usually most observable about the disc, and gradually shades off toward the periphery of the retina. The periphery may be entirely free from any infiltration.

On account of the thinness of the retina at the *macula lutea* the opacity at this spot is less marked; as a result there is an apparent increase of redness at this point, owing to the reflection from the choroidal vessels. The retinal arteries are normal while the veins are usually congested, dark and twisted in their course.

Retinitis Albuminurica (*Nephritic Retinitis*).—This variety of retinitis has been repeatedly observed during the progress of Bright's disease of the kidneys, and often precedes, or is recognized before any of the other symptoms of the latter malady are apparent. The pathological appearances of the retina are thought by some authors to be constant and peculiar; but before the

disease is fully developed the changes which are observable are all included under the forms of inflammation already described. The disc is hyperæmic and its outline indistinct. There is serous infiltration in the vicinity of the disc and this occupies quite a portion of the surrounding retina. The arteries are normal at first, and the veins larger, darker and more tortuous than usual. As the disease advances the above symptoms become more marked and the optic disc may even become swollen and prominent. Now the characteristics of the disease begin to appear. Hæmorrhages are the first and these occur early in many cases. Sometimes they are about the first thing noticed and the most usual position is in the vicinity of the disc and *macula lutea*. Small whitish spots (sometimes yellow or gray) begin to form in the retina around the disc. These develop in size and number and finally coalesce into one large patch, or, as is more usual, form a broad white belt around the disc. This belt is usually separated from the disc by a space which is occupied by grayish infiltration. At the same time whitish dots, or small starlike figures are noticed in the region of the *macula lutea*. These also may run together and perhaps join the belt.

These spots around the *macula lutea*, together with

the whitish belt surrounding the disc, are the most characteristic symptoms of this form of retinitis.

It is often possible to discover Bright's disease before much evidence of it can be gathered from the urine. In cases where it is least expected, the oculist has sometimes to announce to the patient the true nature of his malady, and confirm his diagnosis by an examination of the urine.

The spots which appear in the region of the optic disc and the yellow spot are due to fatty degeneration of blood and of connective tissue. All of the symptoms enumerated differ much in character and degree in individual cases. Similar spots and marks are sometimes present in other forms of retinitis, especially in that form due to constitutional syphilis; but the spots are much paler in the other forms, and those in the region of the *macula lutea* are never star-like as in the nephritic varity. The general history of the case should confirm the diagnosis.

Retinitis Pigmentosa.—In this form of disease not only the retina but often the choroid suffers in a peculiar manner. The appearance of a well developed case cannot well be mistaken for anything else. The disease is said to be congenital, or rather is due to congenital predisposition, and owing to its manner of origin and slow progress it may not be recognized for years.

I have already mentioned physiological pigmentation around the optic disc and pathological pigmentation of the disc itself. In exceptional cases, pigment may be deposited in the retina in the course of optic neuritis; but none of these constitute the disease in question. *Retinitis pigmentosa* usually makes its beginning in the periphery of the fundus upon the nasal side and then extends gradually around, all the while advancing towards the posterior pole. It is characterized by variously shaped black spots of pigment irregularly disposed or gathered into clusters. Some of these spots are round or oval, some have rough jagged edges and others (usually the larger ones) have long narrow processes radiating from them. Often the spots seem disposed to follow the course of the bloodvessels which at times have black streaks or lines side by side with them. The last stages of the disease are characterized by atrophy of the retina and optic nerve, together with changes in the choroid. The latter consist in loss of epithelium in places, exposing the vessels and thus forming light patches which are usually fringed with dark pigment. If the choroidal structure becomes atrophied, the white sclerotic is seen shining through in whitish patches. The vitreous seldom becomes affected. The disease is generally binocular.

Syphilitic Retinitis.—As the name implies, this form

of inflammation occurs in the course of constitutional syphilis. It so frequently closely resembles other forms of retinitis that the patient's history must aid largely in deciding its nature. Spots and opacities resembling those described under albuminuric retinitis form in the region of the yellow spot and optic disc, but they are of a duller hue and less persistent. They come and go, and require only a few days for new ones to appear and old ones to disappear.

The choroid and iris are apt to become implicated in this inflammation and if atrophy of the choroid follows, changes similar to those described under *retinitis pigmentosa* take place.

Retinitis Leucœmia is a very rare disease which sometimes accompanies a disease of the spleen and lymphatic glands. The fundus has a pale orange-red color if examined by diffuse daylight received through a hole in the closed window shutter. The papilla is pale and the retina about it clouded. The retinal vessels, notably the veins, are peculiarly pale. The cloudiness of the retina is striated. Small, irregular, whitish spots are seen in the region of the yellow spot, and these are more numerous towards the periphery of the retina. Sometimes these spots are large and round and fringed with red. Effusions of blood are scattered over the fundus irregularly.

Retinitis Apoplectica.—Hæmorrhages into the retina are not often absent in any marked case of retinitis, but where the tendency to extravasation of blood is very great and the patient is one in whom some disturbance of the general circulation is known to exist, the term *retinitis apoplectica* is applicable. Hæmorrhages into the retina seem governed by no rule as to extent, location or number. They may occur in the outer or in the inner layers. They may lie between the retina and the choroid or may extend inwards and burst through into the vitreous humor. Their location may be such as to partially or completely obscure the retinal vesssls from view or they may lie directly behind these vessels, the latter being seen to pass directly over them. In this form of disease there is usually very little destructive change in the retina itself owing to the slight nature ot the infiltration, but the recurrence ot the trouble is to be expected and it may lead to degeneration of the retina and optic nerve. The appearance of an effusion of blood into the retina, if seen early, is bright red. In all cases hæmorrhages appear much darker than the surrounding fundus and they retain their color a long time. If absorption takes place the spots gradually assume a brighter color, break up and disappear. If, as sometimes happens, they undergo

fatty or pigmentary changes, black spots are the result, and these are more or less permanent.

Atrophy of the Retina is a sequel to many inflammations of the inner parts of the eye. It may involve the whole or only a part of the retinal structure. Atrophy of the retina and atrophy of the optic nerve always go together. The central bloodvessels are much attenuated and reduced in number or else quite lost. The increased thinness of the retina with its loss of reflection renders it very little obstruction to a distinct view of the choroid. Spots of exudation sometimes remain a long time in the retinal tissue, or pigment may become deposited along the course of some of the remaining bloodvessels.

Detachment of the Retina means a separation of the retina from the choroid, and may begin at any point; it may remain small or extend in all directions. The lower half is most often the seat of a detachment. The appearances of a detached portion, if large, are those of a loose folding surface bulging more or less forwards into the vitreous humor, and trembling with each movement of the eye. Its vessels are usually darker than those of the surrounding fundus and there is more or less cloudiness in the part. Sometimes the vessels can be traced in their tortuous course over the folds; but more often their continuity seems broken.

Small detachments are more difficult to see than large ones; their presence may be suspected if slight opacities are noticed at any point, together with a curving of the vessels passing over them.

Tumors of the Retina need but a brief notice here. They are classed either as glioma or as glio-sarcoma, and they present the following ophthalmoscopic symptoms if seen very early in their course; a small protrusion from the surface of the retina at some point with some effusion about it, and perhaps some enlargement of the surrounding vessels.

As this is a disease of childhood, it is seldom seen until a later stage than above described and the first thing usually noticed is a bright shining yellowish reflection from the fundus of the eye, seen by the unaided eye in a favorable light, or by the oblique illumination. With the Ophthalmoscope the growth can be accurately examined so long as the media remain clear. It usually appears nodular and vascular upon its surface, and in color it is either orange, yellow or whitish. The reflection from such an eye is usually similar to that from a cat's eye seen in the darkened room. The further development of the tumor is that of increased growth and protrusion until it occupies the whole surface of the retina, and finally the whole eye.

In Fig. 25 may be seen an illustration of a case of *glioma retinæ* in a very advanced stage. It is a case which occurred in the practice of the author, and, as is frequent in such cases, came into his hands at a late day.

FIG. 25.

Embolism of the Central Artery of the Retina differs in ophthalmoscopic symptoms according to the position in which the embolus is lodged. If in the trunk of the main artery, before it divides, the arterial branches are reduced in size, and are nearly or quite bloodless. The optic disc is pale and transparent, and its vessels anæ-

mic. The veins are either empty or irregularly filled, clots appearing to have formed at various points. The retina soon becomes cloudy, especially at its central portions, and in the region of the *macula lutea*, and the latter assumes the appearance already mentioned under serous retinitis, that is, it looks like a bright spot of effused blood owing to the surrounding retinal infiltration. If the obstruction continues in the artery, atrophy of the retina and disc will be the result. If it becomes gradually absorbed, the circulation may again be restored and the retinal opacity disappear. It is of very rare occurrence.

CHAPTER XIII.

THE FUNDUS OF THE EYE, CONCLUDED.

The Choroid.—It should be remembered that the fundus of every eye is colored by the choroidal pigment and by the choroidal blood vessels. The amount, distribution and color of the former, and the amount and quality of the blood in the latter, modify the color of the fundus in individual cases. The more pigment the fundus contains, the darker its hue. This is owing to the obscuration of its blood vessels, and the sclerotic. When any part of the fundus becomes destitute of pigment, the white sclerotic is seen shining through.

In an ophthalmoscopic examination the following abnormal conditions of the choroid show features of importance; viz., hyperæmia, inflammation, tumors, coloboma, tubercles, rupture, changes in, or causing, myopia, hæmorrhages and detachment.

Hyperæmia.—Unless one eye only is involved, hyperæmia is not easily determined. Even then, the varying conditions of pigmentation may mislead. However, increased caliber and redness of the choroidal vessels at any point should be regarded as partial evidence; and if, added to this, the optic disc is hyperæmic and its

outline indistinct, the evidence is still more complete.

Inflammation of the Choroid (*Choroiditis*).—As in retinitis, several distinct forms of choroiditis are described; the exudative presents the most marked ophthalmoscopic appearances. In the other forms the appearances are less definite.

Exudative Choroiditis (*Choroiditis Disseminata*) is a form of choroidal inflammation in which plastic deposits take place. These deposits may take place at any portion of the fundus, but most often they appear first near the periphery and thence extend towards the posterior pole. Their color is yellowish-white or gray, and often quite dull, and their size and shape are subject to many variations. They may be very small at first (not larger than a mustard seed) but as the disease advances, they are apt to increase in size and to finally coalesce, forming larger and more irregular patches.

A syphilitic form of the disease begins most often by spots of exudation at or near the posterior pole, thence extending by increase of size and number towards the periphery. The spots do not coalesce, and are surrounded by a pale red border. But unless the patient's history confirm the diagnosis, the syphilitic nature of any case cannot be fully determined.

In later stages, the absorption of the exudations begins and progresses until not only they have disap-

peared, but until the choroidal structure in which they were lodged becomes atrophied and patches of the glistening white surface of the sclerotic are seen. Around these white patches a dense border of pigment is collected, and the retinal vessels are seen crossing the patches themselves.

That the exudations are not in the retina is made evident by the fact that the retinal vessels can be seen clearly and uninterruptedly passing over them, and furthermore, in the intervals between the spots the retina appears perfectly normal. But although this disease is usually described separately, it is scarcely necessary to observe that if it is at all severe, the retina and iris both become implicated, and atrophy of the retina and optic nerve are the result. Opacities of the vitreous, either fixed or floating, are not an infrequent accompaniment of the disease.

Tumors of the Choroid.—These are sarcoma and carcinoma; the Ophthalmoscope does not aid in distinguishing between them. At the outset of the disease a small spot or elevation may be seen in the choroid. This gradually increases in size and advances toward the vitreous, causing changes in the retinal structure. Soon an effusion of serum takes place behind the affected portion of the retina, causing detachment of the latter. The detached portion of the

retina can be seen in its wave-like folds, trembling with each motion of the eye. This usually obscures the tumor from view, and the Ophthalmoscope does not disclose it again until it has considerably increased in size. Often the lens or the vitreous humor becomes hazy or opaque, early in the disease, and this prevents any clear observation.

Coloboma of the Choroid.—Coloboma, or fissure of the choroid, is often accompanied by fissure of the ciliary body and of the iris, and sometimes even of the li ; but it may exist independently of all these. The optic disc may also be included in the fissure.

Together with the fissure of the choroid there exists a bulging backwards (staphyloma) of the sclerotic. The fissure is at the lower part of the fundus, and is of congenital origin. It appears as a gray or whitish figure of varying width, extending from the optic disc to the ciliary body, and its color is due to the partial exposure of the sclerotic. Its size, shape and color are dependent upon the extent to which the choroid is deficient. The margins of the figure are clearly defined and usually pigmented, and the course of the retinal vessels, as they cross, is curved or twisted. More or less of the attenuated choroidal structure is usually present between the margins of the fissure, and can be detected.

Tubercles of the Choroid.—These are to be observed in the eyes of tuberculous patients. They are situated in the region of the optic disc, and appear as pale yellow or pale rose-colored spots from 5 mm. to 3 mm. in diameter. The larger ones are somewhat elevated above the level of the choroid. They have a slightly reddish tinge about their margins, but do not present a very marked contrast to the surrounding normal color. Their slight elevation causes the vessels to curve in passing over them. Very exceptionally they are slightly pigmented around their borders. The retina remains normally transparent.

Rupture of the choroid follows injuries to the eye or to the head, such as blows. Hæmorrhage and cloudiness of the vitreous usually follow; but after these are sufficiently absorbed, the presence of one or more whitish streaks may be detected in the choroid, and generally at or near the outer side of the optic disc. The edges of the streaks are clear and sharp, and usually bordered with pigment. The retina often passes intact over the rupture, as shown by the uninterrupted course of its vessels. The course of the rupture is usually vertical, and it may be straight or curved. It is more common to find it consisting of two or more lines of separation than of only one.

Changes of the Choroid in Myopia.—The choroidal

coat undergoes some very marked changes in myopia, especially in myopia of a high degree. In the vicinity of the optic disc, generally at its outer side, the choroid becomes atrophied in the form of a crescent. This is called the myopic crescent, and is frequently accompanied by thinning and bulging backwards of the sclerotic (*staphyloma posticum; sclerectasia posterior.*) The crescent is a white, reflecting surface, and is caused by the sclerotic shining through the atrophied portion of the choroid. Its size may vary much; it may be a very small white arc, or may extend entirely around the disc in the form of a broad white girdle. In the latter case, the term "crescent" does not apply. Small patches of pigment sometimes dot its expanse. The whiteness of the crescent, or girdle, causes the optic disc to appear abnormally pink by contrast.

But instead of a sharply defined crescent at the outer side of the optic disc, or a girdle encircling it, the atrophy of the choroid may take very irregular forms. It may shade off into the surrounding healthy choroid so as to have no distinct outline; it may have branches.

Choroidal Hæmorrhage.—Hæmorrhagic effusions may be wholly confined to the choroid, or they may escape through the retina into the vitreous. They may pass backwards between the choroid and the sclerotic. Hæmorrhages into the choroid may usually be recog-

nized as dark, irregularly shaped, red spots, over which the retinal vessels pass uninterruptedly. Sometimes if the blood spots are very dark, it is impossible to determine if the vessels really pass over them or beneath. They are apt to persist a long time, and some pigment may become deposited about them; but during the process of absorption they become paler and of a yellowish hue; and, if small, may leave no trace behind.

Detachment of the Choroid from the Sclerotic.—This is somewhat analogous to detachment of the retina in its appearance; but it may be distinguished from it by the fact that it does not tremble with the motions of the eye. The retinal vessels may also be distinctly traced over its surface. The protrusion is ovoid in form, and distinctly seen in the erect image. Its surface is smooth and the choroidal vessels can be seen close beneath it.

If the detachment is caused by an effusion of blood, the color of the tumor is dark red; but if caused by serum it is of a yellowish tint. The retina covering the surface of the protrusion may also become partially detached and complicate the appearances.

CHAPTER XIV.

OPHTHALMOSCOPIC OPTOMETRY.*

Ophthalmoscopic Optometry has two objects: 1, the determination of ametropia independently of the statements of the patients; and 2, the measurement of elevations and depressions in the background of the eye.

Perfect relaxation of accommodation on the part of the observer is the first requisite of a correct determination, while the patient is directed to abstain from any accommodative effort by looking into the distance or into vacancy.

As we ascertain the degree of ametropia by measuring the distance of the far-point of the range of accommodation from the cornea, or the anterior principal, or the anterior nodal plane of the eye, it is easily understood that, in determinations by the Ophthalmoscope, the distance of the correcting glass from the examined eye has to be added to the number of the concave lens with which the degree of myopia is ascertained, whereas it has to be substracted from the number of the convex

*This chapter has been taken almost wholly from a pamphlet by Dr. Knapp, and is adapted to his double-disc Ophthalmoscope as has been described. As that instrument is seldom manufactured now, his new single disc instrument being in his opinion much better, it can be easily adapted to the latter instrument, or any other.

glass with which we ascertain the degree of hyperopia. If, for instance,—12 be the weakest glass with which an observer who holds his mirror one inch from the eye of the patient, sees the fundus clearly, the degree of myopia is not 1-12 but 1-13; on the other hand, if + 12 be the strongest positive glass with which he sees the fundus of another patient's eye, the degree of hyperopia is 1-11. Ametropic observers have, of course, to take the degree of their ametropia into account. The simple procedures to do this are too easy to be dwelt on in this place; besides, they are fully explained in Mauthner's *Lehrbuch der Ophthalmoscopie, Wein* 1868, p. 165, etc. As there is, however, some reckoning required for every ophthalmoscopic determination done by ametropic observers, I would recommend them to have the glass which corrects their ametropia inserted additionally into one or both discs, namely into both, if it be a number not found in the series given there. An observer of M1-9, or H1-9, for instance, I would advise to have — 9, respectively + 9, inserted between 48 and O into each disc. He is then able to determine the state of refraction of each eye without ciphering, and just as conveniently as an emmetropic observer. If his degree of ametropia is represented by a glass in one disc, he should have the same number additionally inserted into the other disc. He will then gain another

TABLE

Indicating the ophthalmoscopic determination of elevations or depressions in the background of APHAKIAL EYES.

Number of Convex Glass.	Obtained by Combination.	Position of Fundus in front of 2d princ. Focal plane.
2	....	12.11 mm.
2 4-15	+ 2 — 17	10.73 "
2 1-2	+ 2 — 10	9.75 "
2 2-3	+ 2 — 8	9.18 "
3	....	8.19 "
3 1-5	+ 3 — 48	7.69 "
3 9-17	+ 3 — 20	7.19 "
3 9-11	+ 3 — 14	6.48 "
4	....	6 19 "
4 16-29	+ 4 — 33	5.46 "
5	+ 4 — 20	4.98 "
5 3-5	+ 4 — 14	4.45 "
6	....	4.16 "
6 6-7	+ 6 — 48	3.65 "
8	....	3.13 "
10	....	2.51 "
12	....	2.10 "
14	....	1.80 "
17	....	1.48 "
20	....	1.26 "
24	....	1.13 "
33	....	0.77 "
48	....	0.53 "

opening in the first disc which may be filled by any glass he desires. An astigmatic observer should have an appropriate glass additionally inserted into each disc in the same manner as an ametropic observer, and in case his astigmatism be compound, the additional glass should, of course, correct both his astigmatism and his ametropia.

The second object of Ophthalmoscopic Optometry, *the measurement of elevations and depressions in the fundus oculi*, is accomplished by determining in the erect image the states of refraction of the crest and the basis of an elevation, or the margin and the bottom of a depression. Since the optical apparatus in one and the same eye remains unchanged during the examination, the differences in the state of refraction of different parts in the fundus may be found by calculation. I described this method of ophthalmoscopic determination of the relief of the background of the eye at the *Congres International d' Ophthalmologie*, in Paris, 1867, (see the *Compte-Rendu* of that meeting, p. 165, etc.), and published a table for that purpose in my treatise on the Intra-ocular Tumors (p. 106, English translation). L. Mauthner, too, described the same method in his book on Ophthalmoscopy (1868, p. 206, etc.), and E. G. Loring, in an excellent paper; *Determination of the Optical Condition of the Eye by the Oph-*

thalmoscope, with a new modification of the Instrument for that purpose, Am. Journ. of the Medical Sciences. 1870, p. 323, etc.

The method is, indeed, nothing but the ophthalmoscopic application of the determination of the length of the ocular axis from known degrees of ametropia.

The calculation is as follows: If we apply the general dioptric formula $\frac{F_1}{f_1} + \frac{F_2}{f_2} = 1$ to the eye, and employ for the anterior and posterior principal focal lengths F_1 and F_2, the values $F_1 = 15$ mm. and $F_2 = 20$ mm., according to Listing's reduced eye, we obtain, by ophthalmoscopic observation two conjugate focal lengths, f_1 and f_2. The luminous object is the background of the eye, its image is seen with the Ophthalmoscope, and its position, respecting its conjugate focal distance, is determined by the correcting lens. If we call the conjugate focal distance of the image f_1, and the conjugate focal distance of the luminous object f_2, we determine f_1 by ophthalmoscopic observation, and find f_2 by calculation.

The above-mentioned general dioptric formula,

$$\frac{F_1}{f_1} + \frac{F_2}{f_2} = 1$$

transforms into

$$f_1 = \frac{f_2 F_1}{f_2 - F_2}$$

If we deduct F_1 from both sides of the equation, namely,

$$f_1 - F_1 = \frac{f_2 F_1}{f_2 - F_2} - F_1$$

and reduce this expression, we obtain

$$f_1 - F_1 = \frac{F_1 F_2}{f_2 - F_2}$$

$f_1 - F_1$ in algebraic language signifies the distance between the first conjugate and first principal focal points, and $f_2 - F_2$ means geometrically the distance from the second conjugate to the second principal focal point. Let us put $f_1 - F_1 = l^1$, and $f_2 - F_2 = l^2$, the above formula reads: $l^1 l^2 = F_1 F_2$.

This formula and its deductions are taken from Helmholtz's *Physiologische Optik*, p. 49. For the convenience of calculation we write it:

$$l_2 = \frac{F' F_2}{f_1 - F_1}$$

because f_1 changes with every auxiliary glass. f_1, as we have seen above, does not exactly represent the principal focal length of the auxiliary glass, but its

distance from the eye has to be added in cases of myopia and deducted in cases of hyperopia. This distance may be reduced to 20 millimetres. In examining, in the erect image, the patient's right eye with my right eye, and his left with my left, the mirror can, without inconvenience, be held so near the patient's eye that the auxiliary lens is 14 to 20 mm. distant from the first principal plane, that is, the middle of the anterior chamber of the patient. The mirror then touches the patient's eyebrow, and thus is invariably at the same distance from the examined eye, whereas this distance is apt to vary in different observations, if the mirror has no point of rest on the patient's as well as on the physician's orbital margins. If the mirror is held at some distance from the eye under examination, this distance has to be measured for every available observation; but if one edge of the mirror touches the brow of the patient, the distance of the correcting glass from the anterior principal plane of the examined eye may with sufficient accuracy be assumed to measure 20 mm., which quantity has been used in the calculation of the subsequent table.

I may still remark that, if l_2 is found positive, it lies behind the posterior principal focal plane; if negative, it lies in front of it. *As the table is intended to be a* HELP FOR PRACTICE, *the first column indicates the auxil-*

iary, i. e., *correcting glass, with which the determination is made*, but *h is computed from the real degree of ametropia*, that is as approximately as it can be determined with the lenses which, thus far, are at our disposition, and, as is known, are all more highly numbered than their focal lengths would indicate; for instance, No. 36 is in reality $33\frac{1}{4}$; 20 is $18\frac{1}{2}$, 14 is 13, 9 is $8\frac{1}{2}$, etc.

The table on page 148 will make it easy to *measure the height of elevations, and the depth of depressions in the background of the eye.* If the eye be emmetropic, the quantity corresponding to each auxiliary glass at once indicates in millimetres the elevation or depression of a diseased part. If the eye be hyperopic or myopic, the degree of H or M may first be determined, and afterward the refractive condition of the part, the elevation or depression of which we want to measure. The difference in the refractive conditions of these two determinations refers to two points, situated on the antero-posterior diameter of the globe. Their distance from each other can easily be computed by referring to the table. For instance, an eye, the fundus of which is seen with + 24 is affected with a small intra-ocular tumor, the crest of which is seen with + 6. + 6 corresponds to a shortening of the ocular axis of 1.91 mm., + 24 to a shortening of 0.47. By subtraction we

obtain 1.44 mm. as the height of the tumor. If the eye had shown M 1-24 instead of H 1-24, and the crest of the tumor had shown as before, H 1-6, the elongation of the optical axis corresponding to M 1-24, viz., 0.46 mm. should have been added to 1.91. Then the height of the tumor would have been 2.37 mm. This sort of calculation is so easy to understand that I need give no other examples. The two sets of glasses, however, enable us to determine elevations or depressions without resorting to any calculation, by simply referring to the foregoing table. We determine first either the greatest elevation or the greatest depression of that portion of the fundus the height or depth of which we want to ascertain. For instance, the crest of a tumor, with relaxed accommodation, is seen with + 6. We leave + 6 in its position behind the aperture of the mirror, and diminish its effect by placing concave glasses of increasing strength over it until we see distinctly the basis of the tumor, *i. e.*, the *fundus oculi*. Suppose this is the case with — 8, then it is clear that the eye is hyperopic. Looking up the shortening which corresponds to + 8, we find 1.42 mm., or very nearly the same quantity which we found before by subtraction. The values thus obtained are sufficiently accurate for the weaker numbers only, namely, from 3 to 48, since for the stronger numbers

TABLE

Indicating the ophthalmoscopic determination of the shortening, resp. elongation of the ocular axis by means of positive, resp. negative auxiliary lenses.

Number of Glass.	Obtained by Combination of		Shortening.	Elongation.
2	....	....	6.12	5.08
2 4-15	2	17	4.93	4.23
2 1-2	2	10	4.80	4.14
2 2-3	2	8	4.27	3.90
3	....	....	3.95	3.49
3 1-5	3	48	3.68	3.28
3 9.17	3	20	3.32	2.99
3 9-11	3	14	3.05	2.78
4	....	....	2.91	2.65
4 16-29	4	33	2.63	2.42
5	4	20	2.31	2.14
5 3 5	4	14	2.05	1.92
6	....	....	1.91	1.80
6 6-7	6	48	1.62	1.56
8	....	....	1.42	1.36
10	....	....	1.13	1.09
12	....	....	0.94	0.91
14	....	....	0.80	0.78
17	....	....	0.66	0.65
20	....	....	0.56	0.55
24	....	....	0.467	0.459
33	....	....	0.339	0.335
48	....	....	0.232	0.230

the shortening by a certain positive glass differs too much from the elongation by a negative glass of the same focal length or the same number. For the stronger numbers this method of leaving one glass in position and determining the optical condition of the other surface with the other disc, could be employed only with glasses which are not obtained by combination viz., 2, 3, 4, 6. The refractive intervals between these glasses, and consequently the amount of shortening or elongation of the optical axis corresponding to them, is so great that determinations made with these glasses alone are not sufficiently accurate. The shortening with + 2 is 6.12 mm., that with + 3 is 5.95 mm. This is too great an interval, and therefore the necessity of intermediate numbers. In general, the method of determining independently the optical conditions of various points in the fundus, and the addition or subtraction of the values corresponding to their location as found in the table, is to be employed for the measurement of high elevations and deep depressions, whereas the other method of determining one surface with a glass of one disc, which is left in position, while the other surface is examined with the other disc, is available and preferable in cases of lesser elevations or depressions. In the great majority of instances we have to deal with elevations or depressions

of moderate extent, namely, exudation and excavations, and therefore the simpler method of determination admits of more frequent application.

The shortening of the optical axis relating to convex glasses, as stated in the foregoing table, has no reference to the *aphakial eye*, its optical constants being different from those of the ordinary eye. As elevations and depressions; exudations, excavations, tumors, etc., may occur in the aphakial as well as in the ordinary eye, I have arranged a table also for the aphakial eye.* The calculation is done according to the formula we used for the ordinary eye: $l_2 = \frac{F_1 F_2}{f_1 - F_1}$. The values of F_1 and F_2 are derived from Helmholtz's and my own measurements of the radius of curvature of the cornea. They are $F = 22.6$ mm.; $F_2 = 30.3$ mm.

* See page 141.